CHAPTER 8

Policy Alternatives for Strategic Materials

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The **central premise that underlies concern about strategic materials can be stated as** follows: the United States **must import a number of materials that are essential to the national defense and to domestic industry.** For a number of these materials, the bulk of the supply comes from countries or regions that are either politically unstable or ideologically hostile to the United States. As a result, the United States may face disruptions in the supply of these materials, disruptions that could be damaging to the national defense or industrial strength of the country.

The National Defense Stockpile and the priority allocation system provided under the Defense production Act address the problem of maintaining an adequate supply of materials for national defense. These policies and procedures, however, are not meant to protect the U.S. industrial economy from disruptions in the supply of strategic materials except in times of war or national emergency.

The technical approaches that are the subject of this report can help reduce the vulnerability of the United States to disruptions in the supply of strategic materials. The approaches can be grouped into three categories: mineral production and processing, conservation and recycling, and substitution. Policy options for the implementation of these approaches, including the formulation of coordinated Federal strategies for strategic materials, are the subject of this chapter.

Two general observations apply to the discussion in this chapter. First, most of these technical approaches are long-term in nature. Some of the alternatives, such as the development of substitute materials for the most demanding applications, may require ***10*** years or more to be brought to fruition. Second, private industry, not the Federal Government, is the primary producer, importer, and consumer of strategic materials. Therefore, it is private industry that will make most decisions about the location of new mineral development, about the use of conservation and recycling technologies, and about the development and use of substitute materials.

The Federal Government can influence private decisions through such actions as support of research and development or use of tax and other economic tools to influence investments. The degree of government involvement considered appropriate or desirable depends on the policymaker's assessment of the likelihood and effect of supply disruptions, on his or her philosophy of the relationship of government and industry, and on the economic and technical resources available for this issue in the wide range of national affairs.

Potential Contribution of Alternatives to Specific Material Supplies

Prospects for reducing vulnerability must be assessed on a material-by-material basis. The potential contribution of each alternative differs for each strategic metal under examination; however, taken in sum, these alternatives can contribute significantly to net reduction of U.S. vulnerability to disruptions of supplies of strategic materials.

Table **8-1 illustrates** how each technical alternative relates to the first-tier strategic materials (chromium, cobalt, manganese, and platinum group metals) that are addressed in detail in this study. These alternatives are summarized briefly below. Detailed discussion of the technical alternatives to import vulnerability is provided in chapter 5 (production and processing),

Table 8-1.—Technical Prospects for Reducing U.S. Import Vulnerability for Chromium, Cobalt, Manganese, and the Platinum Group Metals

	Chromium (Cr)	Cobalt (Co)	Manganese (Mn)	Platinum group (PGM)
U.S. apparent consumption (1982)[a]	319,000 short tons	5,592 short tons (1 1,184,000 Ibs)	672,000 short tons	61 short tons (1,787,000 troy ounces)
U.S. import dependence (1982)[a]	85%	92°/0	990/o	800/0
Recycling in 1982 (purchased scrap)[b]	12%	80/0	Not estimated	19°/0 (excludes toll refined)
Domestic production in 1982[a]	0%	0 %	About 2°/0 of apparent consumption	0.40/0 of apparent consumption
Price in 1982[a]	Turkish chromite: $100/short ton ($110/metric) South African: $47/short ton ($52/metric).	Cathode 99°/0 Co: $12.90/pound	About $1.58-$1.68 per long ton unit (22.4 pounds) of 46 to 48°/0 of Mn metallurgical ore.	Dealer Price: platinum —$327/troy oz.; palladium —$67/troy oz.
Value of imports into the United States in 1982[c] (including gross weight)	$120 million	$143 million	$197 million	**$554 million**
Import sources (1979-1982)[a] (Bold-faced countries are primary producers)	Chromite: **South** Africa (480/o); **U.S.S.R. (170/0);** Philippines (130/.); Other (220/0). Ferrochromium: South Africa (440/o); Yugoslavia (90/.); Zimbabwe (90/.); Other (380/.).	Zaire (37%); Zambia (130/o); **Canada** (80/0); Belgium-Luxembourg (80/0); Japan (70/o); Norway (i' "/o); Other (13%).	Ore: **South Africa (330/0); Gabon** (260/o); **Australia (200/0); Brazil (120/0); Other** (9%) Ferromanganese: **South Africa (430/.); France (260/o); Other (31 O/O).**	**South Africa (560/o); U.S.S.R. (160/O); U.K. (11 O/O); Other** (17%).
Location of major world reserves[d]	South Africa and Zimbabwe (920/o); the remaining 8°/0, distributed among more than 10 countries, represents reserves in excess of 100 million short tons of chromite. Chromite typically ranges from 22 to 38°/0 chromium content.	Zaire (500/0); Zambia (130/0); Cuba (70/.); U.S.S.R. (50/o); the remaining 250/. of world reserves (2 million short tons) is distributed among 12 countries.	**South Africa (400/o); U.S.S.R. (370/o); remaining 23°/0 (distributed among 8 countries) represents** reserves in excess **of 200 million short tons.**	South Africa (790/o); U.S.S.R. (190/0); remaining 20/0 (20 million troy ounces) is in Canada, the U. S., and Columbia.
Prospects for increased substitution	Very good for noncritical applications; for critical applications, extensive applied R&D will be needed. Basic research breakthroughs may be needed to develop substitutes in the most critical applications.	Good for many applications; additional R&D needed for critical applications such as superalloys. Qualification requirements may limit practical use of these substitutes.	Poor—substitutes for Mn in steelmaking (which accounts for 900/0 of consumption) are not promising.	Alternatives to PGM exist in many applications; in critical applications, prospects for direct substitution are poor in the near and medium term.
Potential for displacement by advanced materials	Fiber-reinforced plastics and some other composite materials may compete with stainless steels in some critical applications over time.	Reasonable prospects for incremental phase-in of advanced materials in near and medium term; long-term prospects (2010 and beyond) may be great in heat engine applications.	Limited: various composites may compete with steel in specialized applications.	Breakthrough in basic research is probably needed for other materials to replace PGM as a catalyst.
Potential for increased recycling	Good—major obstacles are economic. Reduced downgrading, improved obsolete scrap recovery, and recovery of Cr values from steelmaking wastes appear to be the major opportunities, although data is out-of-date. Scrapped catalytic converter shells could become source of Cr; recovery of Cr from steel making wastes also may add to supplies.	Good—economic factors are primary impediments to recycling, although advanced technologies may have to be developed to maximize recovery of superalloy scrap. Obsolete superalloy scrap, spent catalysts, and other postconsumer uses will be a growing potential source of cobalt. For 1980, an estimated 2,350 short tons (4.7 million Ibs) of Co was not recycled or was downgraded.	Poor—unless technical advances make Mn recovery from slag economical.	Excellent—recycling of PGM from automotive catalysts could provide 400,000 to 500,000 troy ounces of PGM annually in the mid-1990s. Obsolete electronic scrap could also be a major recycling source if high costs of disassembly are overcome.

Table 8=1.—Technical Prospects for Reducing U.S. Import Vulnerability for Chromium, Cobalt, Manganese, and the Platinum Group Metals (Continued)

	Chromium (Cr)	Cobalt (Co)	Manganese (Mn)	Platinum group (PGM)
Potential for more efficient use through design, processing, and manufacturing technologies	Incremental gains; a major breakthrough akin to the AOD process, which reduced chromium losses in stainless steel production is not foreseen.	Very good—in superalloy production and parts fabrication; however, more efficient manufacturing will reduce scrap materials most preferred for recycling.	Good—manganese required per ton of steel could be reduced significantly by the year 2000 (from the current level of 36 lbs/ton to 25 lbs/ton).	Uncertain—will depend on basic research in catalyst chemistry.
Prospects for production and processing:				
Potential for Significant domestic production	Very poor—known deposits are low in quality and probably will not be exploitable except in a national emergency; however possibility of a new discovery of a promising deposit cannot be ruled out entirely In addition, limited quantities of chromite may be produced as a by-product if nickel-cobalt laterites are developed.	Poor—without subsidy or major price rise. Good with subsidy. Maximum simultaneous development from existing mine sites could provide 10 million pounds (5,000 short tons) of cobalt annually for a 10- to 15-year period. Production economics varies by mine site. Mine owners have cited prices ranging from $16 to $25 per pound as needed where cobalt is the primary mine product. At other sites, prices of nickel and copper need to be considered in determining whether coproduction would be profitable.	Very poor—known deposits very low in quality. Possible discovery of a promising deposit cannot be ruled out entirely.	Fair to good—initial plans to develop one domestic site anticipate palladium and platinum production equivalent to 9 % of total U.S. PGM consumption in 1982. A decision on the project is expected in 1985. Much higher production levels may be achievable if other sites are developed.
Potential for supply diversification abroad	Poor to fair—probably would require U.S. development assistance or incentives to promote production in Turkey, the Philippines, and several other countries.	Good prospects—but viability depends on copper and nickel markets because cobalt is a byproduct from mining of these materials. Improved technologies for laterite processing in the U.S. may be transferable overseas.	Good—several alternative suppliers exist, including Mexico, Australia, Brazil, and Gabon.	Poor—unless major new discoveries are made (U.S. has most promising unexploited deposit).
Potential to retain domestic processing capacity	Loss of processing capacity is expected to continue in near term with stabilization of domestic industry at a reduced level in long term to" meet specialty steel industry needs.	Good—processing capacity is expanding due to recycling efforts	Loss of processing capacity is expected to continue in near term with stabilization of industry at a reduced level to meet-specialty steel industry needs.	Good—domestic refining capacity has increased to meet recycling needs.
Prospects for substantial reduction in current levels of U.S. dependence by the year 2000 using the above alternatives.	Fair	Good	Fair	Good
Most promising technical routes to reducing U.S. import dependence by 2000	Substitution Recycling Diversification of supplies	Recycling Design, processing, and manufacturing technologies Domestic production substitution	Continuation of conservation trends in steelmaking Diversification of supplies Replacement of steel in some applications by aluminum or plastics	Recycling of automobile catalysts and electronic scrap Domestic production

[a] U.S. Department of Interior, Bureau of Mines, Mineral *Commodity Summaries 1984* Washington, DC U S Government Printing Off Ice, 19&3) Figures on apparent consumption may differ from apparent consumption figures in table A or ch. 1 because of different reporting conventions used in different Bureau of M ines statistical series

[b] U.S. Department of Interior, Bureau of Mines, *Mineral Commodity* Summaries *1983* (Washington, DC: U.S. Government Printing Of fice, 1982) Estimates of purchased scrap as a percentage Of apparent consumption in 1982 are preliminary estimates which may be subject to revision Appreciable quantities of manganese contained in ferrous and nonferrous scrap and steelmaking slag are recycled Howwer, scrap recovery specifically to recycle manganese is minimal

[c] U.S. Department of Interior, Bureau of Mines, *Minerals* yearbook *Vol I,* Me/a/~ and *Minerals 1982* (Washington, DC: U S Government Printing Off Ice, 1983), table 10, pp. 54-55.

[d] U.S. Department of Interior, Bureau of Mines, "Mineral Commodity Profiles 1983" (chromium, cobalt, manganese, and platinum group metals),

SOURCE: Office of Technology Assessment, 1984.

chapter *6* (conservation and recycling) and chapter 7 (substitution and advanced materials).

Chromium

The United States is dependent on South Africa and the Soviet Union for most of its chromium, half of which is used in stainless steels. Major opportunities exist to conserve chromium, especially in nonessential applications for stainless steel where substitutes (e.g., aluminum and plastic) are widely available. For critical applications, some promising lower chromium stainless steels are now under development—primarily by government. These will need substantial additional work before they will be available for use. In some applications, chromium is so essential that a breakthrough in basic research may be needed to find substitutes. Although recycling of stainless steel scrap has reached a high level, reduced downgrading and improved recovery of obsolete scrap and steelmaking wastes could help add to chromium supplies. Because known domestic chromite deposits are very poor in quality, diversification of foreign suppliers may be a more attractive option than development of known domestic chromite deposits. Discovery of higher quality domestic chromite deposits appears unlikely but cannot be ruled out.

Cobalt

Of the first-tier strategic materials, cobalt offers the greatest range of technical alternatives to current supply patterns, which are dominated by Zaire and Zambia. Ongoing manufacturing trends in the aerospace industry are encouraging highly efficient use of cobalt in the fabrication of jet engine parts, and this trend is likely to continue in the future. With advances in recycling technologies, it should become technically possible to recover much more of the several million pounds of cobalt contained in downgraded scrap or waste that is not recovered each year. Substitutes are already available for cobalt in many applications. In addition, some low-or no-cobalt substitutes have been developed which could replace cobalt in some superalloys-–the application of greatest concern because of their importance in jet engines. These will need to be thoroughly tested and qualified for use before they can be employed. Over the long term—beyond the year 2000—promising advanced materials may increasingly be used in jet engines, potentially reducing the need for superalloy (and hence strategic materials) in this critical application.

Evaluations of known domestic deposits suggest that more than ***10*** million pounds of cobalt could be produced annually for a 15- to 20-year period if the four most promising sites were developed simultaneously. At current cobalt prices, none of these sites would be profitable to develop. Moreover, at some sites, cobalt would be a coproduct or byproduct of other metals production so that production economics would not depend on cobalt alone. Federal subsidies, such as a guaranteed purchase price, would probably be needed for a protracted period for sustained cobalt production to occur.

Manganese

Options for reducing U.S. reliance on the Soviet Union and South Africa for manganese supplies are largely limited to conservation in steelmaking and developing greater diversity among foreign suppliers. The ongoing process of upgrading U.S. steelmaking facilities and processes should make it possible to reduce total manganese requirements (excluding home scrap) for each ton of steel from about ***36*** to ***25*** pounds by the year ***2000.*** Manganese ferroalloy requirements, especially, could be reduced–falling from about 16 to about ***8.3*** pounds per ton by the year ***2000.*** A commitment to changing supply patterns to reduce reliance on South Africa and the Soviet Union could also reduce U.S. vulnerability, since several other major foreign producers exist. As with chromium, virtually no exploitable domestic manganese deposits are known at this time. Unless a major new deposit is found, prospects for significant domestic production will remain slight.

Platinum Group Metals

Alternatives for reducing U.S. dependency on South Africa and the Soviet Union for platinum group metals (PGMs) include increased recycling of automotive catalysts and electronic scrap and development of domestic PGM deposits. Between now and 1995, the annual amount of potentially recoverable PGM from scrapped cars will grow from about ***110,000*** to ***700,000*** troy ounces or more, If 500,000 troy ounces of this were to be recycled, an amount of PGM equivalent to 25 percent of 1982 U.S. PGM consumption for all uses would be added to U.S. supplies. PGMs are of such high cost that they are used very efficiently, and the incentive for conservation is high. The United States also has one of the world's most promising deposits of PGM that has yet to be exploited in the Stillwater Complex of Montana. One mine site in the complex is now being evaluated for possible production, raising the possibility of appreciable domestic production by the end of the decade. Initial plans call for production of about 175,000 troy ounce of PGM, about 9 percent of total U.S. consumption in 1982. Over the long term, much higher production levels may be achievable if additional sites within Stillwater and elsewhere are brought into production,

Existing Laws and Strategic Materials Policy

There are many ways in which the Federal Government can assist and guide the private sector in implementing the aforementioned technical approaches if it chooses. Options range from dissemination of information and data, to sponsorship of research and development (R&D), to provision of incentives and subsidies to encourage private actions. Over the years, congressional concern about strategic materials has led to adoption of several laws which provide a relatively comprehensive statutory framework for Federal activities of this kind. Laws such as the Defense Production Act and the Strategic and Critical Materials Stockpiling Revision Act provide basic authorization to undertake a full panoply of activities related to strategic materials, such as development of substitutes, development of processing technologies, and development of domestic production capabilities when such activities are deemed necessary for national security or would help achieve stockpile objectives.

Two recent Federal laws have emphasized the need for high-level executive branch policy coordination of strategic materials R&D activities. The National Critical Materials Act of 1984 directed the establishment of a National Critical Materials Council in the Executive Office of the President to assist in executive branch strategic material policy formulation and coordination, and oversee a new Federal advanced materials R&D program. The 1980 National Materials and Minerals Policy, Research and Development Act placed increased emphasis on materials R&D in the Federal Government, and articulated a national materials policy. Table ***8-2*** compares the potential contribution of the technical alternatives to material supplies with the degree of government action that may be needed to achieve that contribution, while major Federal laws that provide potential vehicles for implementing these actions are discussed briefly below.

National Materials and Minerals Policy, Research and Development Act (Public Law 96-479)

In 1980, Congress enacted the National Materials and Minerals Policy, Research and Development Act to provide a basic coordinating framework for executive branch material policy decisions. The law gave heightened visibility to substitution, recycling, and conservation as well as to mineral development to meet U.S. material policy objectives, and emphasized the importance of government support for R&D in addressing material problems. A key purpose

Table 8-2.—Probable Degree of Government Involvement Needed in Long-Term Strategies to Reduce Vulnerability

Material alternative	Potential contribution to reduced vulnerability	Extent of government action needed to achieve potential	Nature of government actions: Information and monitoring	Research and development	Direct subsidy to implement alternative	Likely time-frame to achieve outcome once action initiated
Chromium:						
Recycling	Large	Moderate	X	X	No	Near-term
Substitution:						
Noncritical applications	Large	Moderate	X	Possibly	No	Medium-to long-term
Critical applications	Medium	Moderate to extensive	x	X	No	Long-term
Supply diversity	Small to medium	Extensive	X	Possibly	Probably	Long-term
Domestic production	Small, without new discoveries	Extensive	X	X	X	Long-term
Cobalt:						
Recycling and conservation	Large	Moderate to extensive	x	X	Probably not	Near-to medium-term
Domestic production	Large	Extensive	X	X	X	Near-term
Substitution	Medium	Moderate to extensive	X	X	Possibly	Medium-to long-term
Supply diversity	Medium	Extensive	X	Possibly	Probably	Long-term
Manganese:						
Conservation	Large	Modest	X	X	No	Near-to medium-term
Supply diversity	Large	Extensive	X	Possibly	X	Long-term
Domestic production	Small	Extensive	X	X	X	Long-term
Substitution	Small	Not assessed	?	?	?	?
Platinum group metals:						
Recycling and conservation	Large	Modest	X	Minor	No	Near-term
Domestic production	Medium to large	Probably modest	X	Minor	Probably not	Near-term (possible)
Substitution:						
Noncritical applications	Large	Modest	X	No	No	Near-term
Critical applications	Probably small	Not assessed	?	?	?	Long-term
Supply diversity	Probably small	Not assessed	?	?	?	Long-term
***Advanced* materials:**						
Ceramics	Potentially large	Extensive	X	X	Possibly	Long-term
Composites	Potentially large	Extensive	X	X	Possibly	Long-term

KEY:
Large—200/0 or more of 1982 U.S. consumption.
Medium—5 to 20°/0 of 1982 U.S. consumption.
Small—less than 5°/0 of 1982 consumption.

Near-term—within 5 years.
Medium-term—within 15 years.
Long-term–beyond 2000.

Modest—Little required beyond current level.
Moderate-Some new actions needed.
Extensive—Major new actions required.
X = Increased activities in this area.
? = Not assessed.

SOURCE: Office of Technology Assessment.

of the Act was to provide better mechanisms for coordinating Federal material-related programs, which presently are highly decentralized, being administered by a host of agencies with differing missions, objectives, and perspectives.

The Act declared that "it is the continuing policy of the United States to promote an adequate and stable supply of materials necessary to maintain national security, economic wellbeing and industrial production with appropriate attention to a long-term balance between resource production, energy use, a healthy environment, natural resources conservation and social needs."[1]

The 1980 Act encompassed all materials that are related to industrial, military, and essential civilian needs. However, strategic materials were given high visibility in the Act, which defined materials as:

> . . . substances, including minerals, of current or potential use that will be needed to supply the industrial, military and essential civilian needs of the United States in the production of goods or services, including those which are primarily imported or for which there is a prospect of shortages or uncertain supply, or which present opportunities in terms of new physical properties, use, recycling, disposal or substitution . . [2] (The definition excludes food and energy fuels.)

The law also called on the president to submit to Congress, on a one-time basis, a "program plan" containing such existing or prospective proposals and executive branch organization structures "as he finds necessary" to implement key sections of the Act.

In April 1982, president Reagan submitted to congress his materials and minerals program plan required by the Act. The 22-page document summarized actions to be taken in four major areas—land availability, materials research and development, minerals and materials data collection, and the strategic and critical materials stockpile.[3] The plan assigned responsibility for coordination of national materials policy to the Cabinet Council on Natural Resources and the Environment. R&D coordination not involving policy questions was assigned to the interagency Committee on Materials (COMAT), under the direction of the White House Office of Science and Technology Policy (OSTP) Federal Coordinating Council on Science, Engineering, and Technology.

Several concerns have been expressed about the Administration's discharge of its responsibilities to Congress under the ***1980*** Act. The Act required the plan, as a minimum, to contain a program, budget, and organizational structure for "continuing long-range analysis of materials use to meet national security, economic, and social needs. " The plan refers to a review of the Federal minerals and materials data system, but makes no specific reference to establishment of a continuing long-range analysis of materials, and also did not provide a budget proposal.

The President's plan also drew criticism for overlooking some key areas of emphasis in the Act. The report focused primarily on minerals availability issues associated with Federal lands and on the management of the stockpile; substantially less emphasis was given to the R&D components of the 1980 Act. Nor did it address recycling, conservation, and substitution in detail. Although the Act provided the President with substantial discretion to select plan components, critics contended that the failure to address these issues made the President's plan inadequate to fulfill the intent of the Act.

Other implementation difficulties were identified by the U.S. General Accounting Office (GAO) in a 1984 report to Congress on overall executive branch responses to the law.[4] GAO pointed out that not all agencies with important materials responsibilities were represented on the Cabinet Council on Natural Resources and the Environment, charged with overall policy coordination. Additionally, GAO found that

[1] Public Law 96-479, sec. 3.
[2] Public Law 96-479, sec. 2(b).
[3] The White House, National Materials and Minerals Program Plan and Report to Congress (Washington, DC: N. P.) April 1982.

[4] U.S. General Accounting Office, Implementation *of* the National Minerals and Materials Policy Needs Better Coordination and Focus (Washington, DC: U.S. General Accounting Office, Mar. 20, 1984), GAO/RCED-84-63.

some agencies have made key materials policy decisions independent of council clearance.

The effectiveness of COMAT in providing information for R&D policy decisions was questioned. According to GAO, the President's fiscal year *1984* budget included an unexpected ***$38* million** for a major new initiative in materials sciences research by the Department of Energy's (DOE) Lawrence Berkeley Laboratory in which COMAT and even the Cabinet Council had little input. The overall goal of this initiative was to improve linkages among academic, national laboratory, and industry scientists for the future advancement of high-technology industries—a responsibility the President's plan delegated to COMAT. However, the policy decision concerning redirection of Federal materials R&D and the appropriateness of DOE's initiative were made independently by the Director of OSTP before COMAT had formulated a position on the need for a new initiative. Moreover, the Cabinet Council had not reviewed the need for this program, nor had it been developed within the context of an overall national materials and minerals R&D program. Another instance cited by GAO was the failure by the Department of Defense to coordinate with the Cabinet Council before seeking funds to subsidize domestic mineral production capacity under Title III of the Defense Production Act.

Several strategic materials reports required by law either have been submitted late or not at all. First, Congress mandated OSTP to prepare and annually revise "an assessment of national material needs arising from scientific and technological concerns over the next 5 years" and where possible, over the next *10* or *25* years. As of March *1984,* the initial report had not been done, and the office informed GAO that it had no plans to undertake the study. (The law did not specify a date for submitting the report.)

The Department of Defense told GAO that it had prepared a report "assessing critical material needs related to national security" and "steps necessary to meet those needs" which was required by the Act. " However, the report was required to be submitted to Congress by October *21, 1981.* As of March *1984,* the report had not been submitted, apparently because it was still under review by the Administration. A Department of the Interior report, also due in October *1981,* was not submitted until November 1983. Only the Commerce Department complied fully with the Act. (A more detailed summary of GAO's findings can be found in box 4-A in ch. 4.)

Despite the Administration's failure to fulfill the information needs of Congress, many individual agencies appear to be carrying out their own activities in a way that is reasonably responsive to the law. Strategic materials R&D funding has fared well in a time of budget cuts, and many other initiatives have been undertaken that were not specifically identified in the President's plan. For example, in *1984,* the Secretary of the Interior, who also serves as Chairman of the Cabinet Council on Natural Resources and the Environment, created a National Strategic Materials and Minerals Program Advisory Committee.

National Critical Materials Act of 1984 (Public Law 98-373)

Signed into law by President Reagan on July 31, 1984, Title II of Public Law *98-373* establishes a statutory National Critical Materials Council "under and reporting to" the Executive Office of the President to advise and assist the President in formulating critical material policies. The Council is also given key responsibilities in developing a "national Federal program" for advanced materials research and technology, and stimulating innovation and technology utilization in basic and advanced materials industries.

Authorization for Title II will expire on September *30, 1990,* unless extended by Congress. The three members of the Council are to be appointed by the President, with advice and consent of the Senate if the appointee is not already a Senate-confirmed government official. One member is to be designated Chairman of the Council by the President. In selecting members, particular emphasis is to be given to people with training, experience and achievement in materials policy, science or engineering, and at least one member is to have a background and understanding of environmental issues. The Council is directed to appoint a full-time Executive Director, who is authorized to employ a staff of up to 12 people in carrying out the Council's duties under the act, and develop, subject to Council approval, rules and regulations needed to carry out the Act's purposes, The law authorizes the appropriation of $500,000 for fiscal year 1985, and thereafter, such sums as maybe necessary. As mentioned, Title II authorities will expire at the end of fiscal year 1990 unless specifically extended by Congress.

The Council, among other things, will: 1) assist in establishing responsibilities and provide for coordination and implementation of critical materials policies (including research and technology) among Federal agencies; 2) bring materials issues deemed critical to the Nation's economic and strategic health to the attention of the President, Congress, and the general public; and 3) ensure continuing consultation with the private sector in matters related to critical materials; materials research, development, and use; and Federal materials policies.

In accomplishing these responsibilities, the Council is to review and appraise Federal agency programs to determine the extent to which they contribute to achieving the policy and directions given by the 1980 National Materials and Minerals Policy, Research and Development Act. It is also to be involved in recommending budget priorities to the Office of Management and Budget (OMB) for materials activities by each Federal agency and department.

By April 1, 1985, the Council was to submit to Congress a report on critical materials inventories, and prospective needs for these materials by government and industry, One component of this report is to be a long-range assessment, prepared in conjunction with OSTP, on prospective critical materials problems, and to advise about how to address these problems. The Council is to review and update its report and assessment as appropriate, and is to report to Congress at least biennially. The Council is also to recommend to Congress changes in current policies, activities, and regulations, as well as new legislation, needed to achieve the intent of Public Law 98-373, and Public Law 96-479.

The Council is given a major role in developing and overseeing the national Federal program for advanced materials research and technology called for by the Act. It is to establish a Federal program plan for R&D in this area, identifying responsibilities for carrying out the research and providing for coordination among the Office of Management and Budget, the Office of Science and Technology policy, and other appropriate agencies and offices. The Council is to annually review, and to report to Congress, on the Federal R&D plan.

The Council is to annually review the materials research, development, and technology authorization requests and budgets of all Federal agencies to ensure close coordination of program goals and directions with policies determined by the Council. The Office of Management and Budget is to consider authorization requests in these areas as an "integrated, coherent, multiagency request" to be reviewed by the Council and OMB for its adherence to the national Federal materials program plan in effect for that fiscal year.

To promote innovation in the basic and advanced materials industries, the Council is to evaluate and make recommendations about establishing Centers for Industrial Technology as provided for by the Stevenson-Wydler Technology Innovation Act of 1980, which is discussed subsequently. The activities of such nonprofit centers, initially funded by Government but intended to become self-sufficient after 5 years, would focus on generic materials research.

The Council is directed to establish, in cooperation with other agencies and private industry, a mechanism for the efficient and timely dissemination of materials property data. This is intended to promote innovation and better use of materials in design. Possible establishment of a computerized material property data system (using existing resources to the extent practicable) is to be considered.

Public Law 98-373, like Public Law 96-479 before it, is in many respects process-oriented legislation, intended to give the Executive Office of the President key responsibilities for critical materials policy. Within the framework established by the law, the executive branch is given considerable discretion and flexibility to establish goals, objectives, and priorities for critical and advanced material programs. The law, for example, does not specifically define the terms "advanced materials" and "critical materials, " but instead uses the broad definition of materials provided by public Law 96-479.

Defense Production Act (50 U.S. C. 2061 et seq.)

Enacted in 1950, the Defense Production Act (DPA) provides several mechanisms for assuring availability of materials and industrial capabilities needed for the national defense. Title I authorizes government priorities for allocation of materials in a congressionally or presidentially proclaimed national emergency or war.

Title 111 authorizes the President to support private activities which would expedite "production and deliveries or services" in aid of national defense. Loans and loan guarantees are authorized for expansion of capacity, development of technological processes, or the production of essential materials, including exploration, development, and mining of strategic metals. Purchases and purchase commitments are authorized for metals, minerals, and other materials for government use or resale. The President is also authorized to "make provision for the development of substitutes for strategic and critical materials" when "in his judgment it will aid the national defense. " Materials considered excess to DPA requirements can be transferred to the national stockpile. Title 111 assistance can be used both domestically and abroad.

In its 1984 reauthorization of DPA (Public Law 98-265), Congress established new procedures for authorization of Title III projects which apply when a congressionally or presidentially declared national emergency is not in effect. Among other things, the law requires the President to determine that federally supported projects meet essential defense needs and that the Federal support offered would be the most "cost-effective, expedient, and practical alternatives for meeting the need, " The law requires "industrial resource shortfalls" for which Title 111 assistance is sought to be identified in the budget (or budget amendments) submitted to Congress. If more than $25 million in aggregate Federal assistance would be entailed to meet the industrial resource shortfall, specific authorization by law would be required.

Historically, DPA has been used primarily to encourage mining of strategic minerals in this country and abroad. The instruments provided in the law, however, could potentially be used for development of substitutes, advanced recycling technologies and other technical innovations considered desirable for national security. In addition, DPA is now viewed as a means to secure supplies and essential processing capabilities for advanced materials needed for defense purposes.

Strategic and Critical Materials Stock Piling Revision Act (Public Law 96-41)

In 1979, Congress revised and updated prior laws related to the National Defense Stockpile through enactment of Public Law 96-41. The law resolved several issues related to changing executive branch strategies for stockpile management among successive administrations. Among other things, it stated that the stockpile was for the purpose of national defense only, and established a statutory stockpile goal of having a 3-year supply of materials on hand to meet national defense, industrial and essential civilian needs in a national defense emergency or war. It also established a stockpile transaction fund so that sales of excess materials could be used to acquire new materials consistent with stockpile goals.

Several provisions in the Stockpile Revision Act have indirect relevance to government support of private activities related to strategic materials. The law calls for maximum feasible use of competitive procedures for stockpile acquisitions; however, waivers are authorized, and this could provide a basis for supply diversification on an ad hoc basis.

The law authorizes upgrading of already stockpiled materials through refining and processing so that they will be in the form most suited to current needs. This has prompted the considerable interest of domestic processors. A panel of the American Society for Metals (AS M), for example, recommended in August 1983 that sufficient quantities of substandard cobalt from the stockpile be provided to industry in order that it could test capabilities to upgrade the material to current standards,' Of the 46 million pounds of cobalt in the stockpile, 40.8 million pounds were acquired in the 1947-61 period. More stringent requirements and consumer specifications have made much of this cobalt inadequate to meet today's demanding requirements for many critical applications unless the cobalt is upgraded. The ASM panel recommended pilot tests with cooperating private firms to identify preferred procedures to upgrade the cobalt quality so that it could be used immediately in a crisis. The recommendation is under consideration by the General Services Administration (GSA) and Federal Emergency Management Agency (FEMA).

As in the prior stockpiling law, the 1979 Act calls on the President to make "scientific, technologic and economic investigations" concerning ''development, mining, preparation, treatment and utilization of ores and other mineral substances , . ." These investigations, delegated by the President to the Secretary of the Interior, are to be carried out to determine and develop "new domestic supply sources; devise methods for treatment and use of lower grade ores and mineral substances; develop substitutes for essential ores and mineral s." Investigations may be carried out on public lands, and with the consent of the owner, on private lands "for the purpose of exploring and determining the extent and quality of deposits of such minerals, the most suitable methods of mining and beneficiating such materials, and the cost at which the mineral or metals may be produced.'"

Stevenson-Wydler Technology Innovation Act of 1980 (Public Law 96-480)

The Stevenson-Wydler Act is intended to promote development and diffusion of new industrial technologies in the United States. The law gives the Secretary of Commerce, in cooperation with other relevant agencies, key responsibilities in stimulating transfer and diffusion of information about federally funded technology development to the private sector and to State or local governments. It requires each Federal laboratory to establish an Office of Research and Technology Applications to facilitate information transfer about activities within the lab that have potential for successful application by industry. In addition, the law established a central Federal clearinghouse (called the Center for Utilization of Federal Technology) to collect and disseminate information about federally owned or originated technologies. (This function has been assigned by the Commerce Department to the National Technical Information Service.)

The Act also directed the Secretary of Commerce to assist in the establishment of "centers for industrial technologies''—centers affiliated with university or nonprofit institutions set up to enhance technological innovations, The Reagan Administration, on November 17, 1983, revoked rules for making grants for such centers. At the same time, it also promulgated rules for a program for promotion of private sector industrial technology partnerships, indicating that this program was intended to supercede the generic technology center program.[7] The new Administration program provides information support to industrial technology part-

[5]American Society of Metals, *Quality Assessment of National Defense Stockpile Cobalt Inventory*, prepared for the Federal Emergency Management Agency (Metals Park, OH: American Societies of Metals, 1983).

[6]Public Law 96-41, sec 8(a]. This provis ion is a cent i nuation of similar provisions in prior stockpiling laws.

[7]*Federal Register*, vol. 48, No. 223, N ov. 17, 1983, p. 52289.

nerships and cooperative R&D arrangements of corporations, nonprofit organizations, and government.

The Stevenson-Wydler Act also directed the National Science Foundation (NSF) to assist in the support of "centers for industrial technology" under the Act. According to a 1984 Administration report on implementation of Public Law 96-480, NSF's previously existing program of support for university/industry cooperative research centers is being used to meet the requirements of the Act in this respect.[8]

The newly enacted National Critical Materials Act of 1984 directs the National Critical Materials Council established by this law to evaluate and make recommendations about establishment of Centers for Industrial Technology to promote innovation and increased productivity in basic and advanced materials industries. Among the activities identified for possible Center involvement were corrosion, welding and joining of materials, advanced processing and fabrication technologies, microfabrication, and fracture fatigue.

[8] Secretary of Commerce, *The Stevenson- Wydler Technology innovation Act of 1980,* Report to the President and Congress (Washington, DC: U.S. Department of Commerce, February 1984). According to the report, which was required by Public Law 96-480, the National Science Foundation, in fiscal year 1983, was supporting eight university/industry centers, including two centers on polymers, one on ceramics, and one on welding.

Formulation of Strategic Materials Policy

In formulating long-term technical strategies for reducing import dependency, the full range of available-options, on a material-by-material basis, must be considered. In some instances, there may be several options available for each material. These options could potentially ease import vulnerability, but entail different costs and different levels of security. In the case of cobalt, import vulnerability could be reduced in several ways, including domestic production, recycling, and substitution. Domestic production, for example, could make a major contribution to domestic cobalt supplies, with complete supply security, but only at a cost to the government (at 1983 prices) far higher than simply purchasing cobalt for the stockpile from world markets. Other options, such as developing promising recycling technologies to the point where they could be used by industry would cost less, but would also entail greater risk, since it cannot be certain that a given research technology will be commercially viable. It is noteworthy that the implementation of these and other technical approaches to reducing cobalt import vulnerability all entail increased government support.

In other instances, as in the case of PGMs, substantial long-term reductions in import vulnerability may be achievable with little government action, Private industry is already well-positioned to take advantage of the growing inventory of PGMs that could be recycled from automotive catalysts as cars are scrapped; and, with some limited increase in PGM prices, nearly *10* percent of current domestic needs could be provided from one U.S. site, with additional production possible from other sites in the longer term. Continued monitoring of industry trends will be needed, but unless one assumes that a PGM supply disruption is likely in the near term, government action to encourage recycling or domestic production is probably not needed at this time.

Experience has shown that development of overall Federal strategies to reduce import vulnerability is a highly complex task. Several Federal agencies have important research responsibilities in the materials field, including the Departments of Defense, Interior, Energy, and Commerce; and the National Aeronautics and Space Administration (NASA). FEMA has lead agency responsibility for coordination of stockpile planning, and GSA administers it. Many other Federal departments and regulatory agencies have indirect effects on materials policy through tax policies, regulation of commerce, environmental protection, Federal land management, antitrust enforcement, patent policy, foreign affairs and trade policy, and other activities. (Selected executive branch agencies with direct responsibilities for strategic materials are shown in table 8-3.)

This decentralization is, to a certain extent, unavoidable, and may even be desirable, but it has made the job of formulating strategic materials policy difficult for both Congress and the executive branch. Congress itself has many different committees with jurisdictional areas related to strategic materials, including (among others) House Committees on Armed Services; Banking, Finance, and Urban Affairs; Science and Technology; and Interior and Insular Affairs; and Senate Committees on Armed Services; Banking, Housing, and Urban Affairs; Commerce, Science, and Transportation; and Energy and Natural Resources. Appropriation subcommittees are even more diverse.

Through enactment of the National Critical Materials Act of 1984 and the National Materials and Minerals Policy, Research and Development Act of 1980, Congress has firmly placed statutory responsibility for coordinating Federal agency activities and decisionmaking with regard to strategic materials research in the Executive Office of the president. The policy planning and coordination procedures required by the 1980 Act, together with the statutory establishment of the National Critical Materials Council "under and reporting to" the Executive Office of the president by the 1984 Act, may in time provide coordinated and coherent strategies to guide Federal agency activities to reduce import vulnerability.

As the Administration begins to implement its new mandate, congressional oversight of the Administration's progress in the continuing implementation of both the 1980 and 1984 laws will be important. Both laws give the Administration considerable flexibility and latitude in developing strategies to address strategic materials issues. They are oriented towards development of effective processes to formulate, coordinate, and implement materials policy programs, and by and large do not dictate substance. This flexibility could lead to highly innovative initiatives in the materials field, but it also means that continuing congressional guidance may be needed at times to assure that the intent of the the two laws is met.

OTA's analysis of oversight issues has focused on two specific issues that may be particularly relevant as the Administration begins to implement the ***1984*** Act: establishing policy goals, objectives, and priorities for strategic materials, and upgrading information about Federal strategic materials R&D activities as a key step in interagency coordination. These issues are discussed below and are summarized in table ***8-4.***

Goals, Objectives, and Priorities of Strategic Materials Policy

A long-term commitment is needed if technical approaches to the reduction of strategic materials vulnerability are to succeed. Moreover, the combination of technical approaches effective for one material will often be inappropriate for another. Recognition that effective planning and policy formulation procedures by the executive branch were needed to develop coordinated goals, objectives, and strategies for materials research led to enactment of the National Materials and Minerals Policy, Research and Development Act of 1980. However, the expectation that this law would lead to an effective policy structure for coordination of strategic material activities throughout the government has not been fully realized, as has been discussed.

With adoption of the National Critical Materials Act of 1984, prospects for improving the executive branch policy structure will hinge to **a** considerable extent on the effectiveness of the new National Critical Materials Council in the Executive Office of the President. Section 205(a) of the law gives the Council "specific responsibility for overseeing and collaborating" with Federal agencies and departments "relative to materials research and development policies and programs. " In this role, the Council is mandated to annually review both the authorization requests and budget proposals of all Federal agencies conducting ma-

Table 8-3.—Selected Federal Agencies With Strategic Material Responsibilities

Agency/department	Policy development						Research and development							Securing material supplies/maintaining domestic processing capabilities				Comments
	Policy coordination	Budget review	R&D coordination	Reports to Congress	Problem assessment	Statutory responsibilities under P.L. 96-479 or P.L. 98-373	Exploration and minerals data	Mining/minerals processing	Materials conservation	Recycling	Substitution	Advanced materials	Material property data	Stockpile management	Emergency allocation	Defense production act incentives	Supply diversification abroad	
Executive Office of the President:																		EOP assigned overall responsibility for policy and R&D coordination by the National Materials and Minerals Policy, Research and Development Act of 1980 (P.L. 96-479). The National Critical Materials Act of 1984 statutorily established the National Critical Materials Council to assist and advise the President on critical materials and advanced materials policy (P.L. 98-373).
Cabinet Council and Natural Resources and Environment	X																	
Office of Science and Technology Policy			X	X	X	X												
Office of Management and Budget		X				X												
(National Critical Materials Council)	X	X	X	X	X	X	—Coordinates R&D—											
Department of Commerce National Bureau of Standards				**X**	**X**	**X**			**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**		**Under P.L. 95-479, DOC has statutory responsibility, assigned to the Office of Strategic Resources, for preparing case studies of material problems**
Department of Defense and Individual Services				X	X	X			X	X	X	X	X	X	X	X		P.L. 96-479 required DOD to submit a Congressional report on National Security needs for materials by Oct. 21, 1981. As of March 1984, the report was still under administration review
Department of Energy and National Laboratories									**X**	**X**	**X**	**X**	**X**			**X**		
Department of the Interior			X		X	X												The Secretary of Interior serves as Chairman of the Cabinet Council and Natural Resources and Environment, assigned overall policy responsibility for strategic materials by President Reagan. The Secretary has established an advisory panel on strategic materials to assist the Department in its strategic material programs.
Bureau of Mines							X	X	X	X	X	X					X	
Geological Service							X	X									X	
National Aeronautics and Space Administration									**X**	**X**	**X**	**X**	**X**			**X**		
Federal Emergency Management Agency				X			—Supports R&D—							X	X	X	X	FEMA is a lead coordinating agency in stockpile management policy
General Services Administration				**X**										**X**	**X**	**X**	**X**	**GSA administers the stockpile**
National Science Foundation					X		—Supports R&D—											
International Development Cooperation Agency																	**X**	
Export-Inport Bank																X	X	

SOURCE: Office of Technology Assessment

Table 8-4.—Policy Alternatives for Formulation of Strategic Materials Policy

		Arguments for/against	
Problem/issue	Option	Positive	Negative
1. The executive branch has had difficulty in establishing overall goals, objectives, and priorities for strategic materials R&D policy. As a result, Federal agency activities are not guided by a coherent, overall strategy for long-term reduction in import vulnerability.	Direct the National Critical Materials Council established by Public Law 98-373 to develop a long-term strategy for Federal strategic materials activities, including goals and objectives by which individual agency activities can be monitored. The multi-year strategy could be revised on a 4-year basis by the Executive Office of the President, giving Congress the opportunity to review progress, provide guidance and clarification as needed.	Clear direction for strategic materials policy and long-range plans to address specific material needs is required to give continuity and ensure appropriate follow-through for strategic material research.	Overly specific congressional guidance could result in inflexible agency response. Periodic revision of the overall strategic materials plan could lead to excessive time and expenditures devoted to policy formulation and planning activities.
2. Federal R&D activities related to strategic materials are dispersed over a large number of agencies. To coordinate R&D policy, conduct oversight and establish priorities, improved survey information is needed.	Instruct the National Critical Materials Council to give high priority to section 209(a)(3) of Public Law 98-373 which calls for cataloging R&D activity as fully as possible. Such a catalog, if undertaken on a material-by-material and objective-by-objective basis, with updates on a regular schedule, would be useful in the budget review activities of the council and would help identify progress towards meeting goals.	Would give decisionmakers information needed to monitor multi-agency responses to overall strategic material goals, identify areas of overlap or duplication of effort, and areas where insufficient R&. D is conducted.	Could lead to overemphasis on strategic materials R&D to the detriment of other needed materials research in agency R&D program planning.

SOURCE Off Ice of Technology Assessment.

terials R&D to "ensure close coordination of the goals and directions of such programs with the policies determined by the Council. " This process is to be coordinated with the Office of Management and Budget, which is to consider material budget proposals as a coherent multi-agency request. The new law requires the Council to prepare and annually revise a Federal program plan for advanced materials R&D.

It seems unlikely that the Council will be able to succeed in its coordinating functions unless it is able to articulate overall goals, objectives, and priorities that could guide strategic materials R&D policy. One important question is whether Federal research objectives should be set broadly—i.e., strategic materials in general—or should be targeted as closely as practical to those materials considered to be most vulnerable. By and large, the approach taken over the years, and which still prevails, is to address strategic materials in a generic sense. This allows agencies to adopt a flexible approach in their research programs, but without centralized administration guidance, it also results in diffusion of efforts among many materials.

An alternative approach would be for the Council to give greatest priority to those materials that are most vulnerable to a supply disruption and most critical to the United States.

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Such an approach presents some problems. First, one cannot know in advance which materials will actually be subject to a supply disruption, so a danger exists that the wrong materials will be targeted. Inflexible administration and rigid adherence to outdated objectives and strategies could also be potential problems. Furthermore, much materials research is not specific to individual metals, and such research might not receive support if forced into a material-by-material evaluation in determining support for R&D activities. However, viewed as a policy tool for establishing overall Federal goals and objectives and for selecting among alternative strategies for achieving them, the material-specific approach could give a clearer sense of direction to Federal efforts to combat materials vulnerability.[9] An effective strategy, therefore, might very well involve a combination of both the generic and material specific approaches to achieve the objective of reduced import vulnerability.

Federal program planning for strategic materials needs to reflect long-term objectives, while still being adaptive and flexible in light of changing circumstances. The 1984 Act's budget review mechanism in theory provides a vehicle for infusing a longer term perspective into agency planning than is provided by the annual budget-setting process.

This connection is most explicit in the case of advanced materials R&D, through Public Law 98-373's requirement that the Council develop and annually revise a Federal program plan for advanced materials research and technology. The law itself does not specify the components of this plan, nor does it specifically define the term "advanced materials." However, the House Committee on Science and Technology, in its report on the bill, indicated its intention that the plan include at least four elements, including "a listing of major existing Federal material research and technology programs—to include existing funding and goals as well as proposed funding levels over the next 5 years." Other plan elements identified by the Committee were: "an assessment of current national materials research and technology needs and problems . . . identification of priorities for research to address those needs or problems, " and "recommendations for program initiatives and changes to meet policies and goals as set forth by the Council."[10]

While the law may not explicitly require such a plan for strategic materials R&D, such an approach might well be effective should the Council choose to pursue it. If a more active congressional role is desired, one option (table ***8-4,*** issue ***1)*** would be for the executive branch to prepare and submit to Congress a multi-year strategic materials plan of action on a periodic basis–say once every 4 years. Congress would then have the opportunity to review the plan's goals and objectives, along with specific measures and estimated funding levels needed to achieve them.

The multi-year plan could then serve as a kind of benchmark by which the Council and Congress could evaluate annual budget requests with respect to strategic materials R&D activities. In reviewing the plan, Congress could give the Council and the Executive Office of the President–which have overall responsibility for materials coordination—additional guidance on specific issues related to the multi-year plan.

Structured into the Act is considerable opportunity for congressional review and oversight of the Council's activities, through its biennial reporting on critical materials to Congress, its annual reporting to Congress on the national Federal advanced materials program plan, and its charge to recommend, when appropriate, changes in current policies, activities, and regulations, and additional legislation that may be needed to carry out materials policy.

In the end, the selection of a framework for policy formulation depends on the extent to which Congress wishes to be involved in setting the overall direction, goals, and objectives

9The need for material specific approaches to reduce export vulnerability has been discussed by the U.S. General Accounting Office, Report to the Secretary of Interior (GAO/EMO-82-69), June 3, 1982.

10House Report 98-593, Part I, **pp. 38-39.**

for strategic materials policy, and the extent to which it wishes to delegate that function to the executive branch. Establishment of the National Critical Materials Council, and the continuing planning processes required by the 1980 Act, clearly provides legislative authorization for effective policy planning by the executive branch. However, without legislative oversight and guidance when needed, there is no assurance that current or future administrations will fully use these policy tools to effectively formulate executive branch strategic materials policies.

Providing Information About Federal Research and Development Activities

A sustained program of Federal R&D will be the cornerstone of any long-term strategy to reduce U.S. materials vulnerability using the technical alternatives considered in this report. In the last decade, strategic materials R&D has received increased emphasis, and recent levels of research funds appear to be quite healthy, However, concern exists about the adequacy of current coordination mechanisms at the interagency level, especially as they relate to the formulation of policy.

The Federal Government is the primary sponsor of R&D activities related to strategic materials. It is also the primary sponsor of basic and applied research related to development of advanced materials. This is consistent with the administration's position that Federal support for R&D should focus on high-risk or long-term areas that may not otherwise be addressed by industry.

In fiscal year 1980, about 4 percent ($67 million) of the total Federal materials R&D budget was directed at strategic materials (excluding advanced materials).[11] As shown in tables 8-5 and 8-6, nearly 40 percent of this budget was for chromium research, followed by aluminum, titanium, nickel, and cobalt. Most of this research was conducted or sponsored by DOE national laboratories, the Bureau of Mines, NASA, the National Bureau of Standards (NBS), and various components of the Defense Department.

Fiscal year 1980 was the last year for which the executive branch has published comprehensive information about strategic materials R&D activities on a material-by-material basis. Detailed information of the sort portrayed in the tables have not been issued for subsequent years on a governmentwide basis. However, it appears that strategic materials R&D has not been greatly affected by the general trend toward reduction of research budgets that has affected other areas, although some strategic materials programs (e.g., NASA's conservation of strategic aerospace materials program) have been cut back.

Federally funded R&D has been the driving force behind the development of advanced materials. Total Federal expenditures for structural ceramics R&D were $23 million in fiscal year 1982.[12] By fiscal year 1984, Federal expenditures had grown to over $40 million. Recent figures are not available about composite R&D funding. However, in fiscal year 1980, over $80 million in composites R&D were expended by Federal agencies. Advanced materials R&D activities are undertaken by several Federal agencies, including the Department of Defense, NASA, DOE, NBS, and the National Science Foundation.

A central thrust of both the National Critical Materials Act of 1984 and the National Materials and Minerals Policy, Research and Development Act is to establish a mechanism that would replace ad hoc materials and minerals decisionmaking within the executive branch with a coordinated Federal R&D policy. As mentioned, the President's 1982 materials plan reestablished COMAT under the direction of the Federal Coordinating Council on Science, Engineering and Technology (FCCSET)

[11] U.S. Department of Commerce National Bureau of Standards, *Survey: Materials Life Cycle Research and Development in the Federal Government Fiscal Year 1980* (NBSIR 81-2359 DOE) (Washington, DC: U.S. Department of Commerce, September 1981).

[12] U.S. Department of Commerce, *A Competitive Assessment of the U.S. Advanced Ceramics Industry* (Springfield, VA: National Technical Information Service, 1984), p. 23.

Table 8-5.—Distribution of R&D Funding for Critical Materials by Materials and by Technology Goal* ($1000)

Technology Element	Substitution	New sources	Reclamation	Life extension	Conservation	Total direct	Total related	Total	Agency†
Chromlum	**4,546** **1,060**	**961** **1,020**	**260** **270**	**20,270** **1,300**	**540** **200**	**26,577** **—**	**—** **3,850**	**30,427**	**1, 3, 4**
Aluminum	— 8,000	1,676 —	— —	800 —	— —	2,476 —	— 8,000	10,476	1, 2, 3
Titanium	**850** **3,600**	**301** **—**	**—** **210**	**2,370** **—**	**—** **500**	**3,521** **—**	**—** **4,310**	**7,831**	**1, 2, 3, 4**
Nickel	807 500	1,662 549	150 470	1,100 1,530	325 700	4,044 —	— 3,749	7,793	1, 4
Cobalt	**670** **300**	**2,216** **520**	**150** **200**	**770** **230**	**—** **—**	**3,806** **—**	**—** **1,250**	**5,056**	**1, 3, 4, 5**
Nioblum	2,000 —	212 —	— 70	1,400 —	— 500	3,612 —	— 570	4,182	1, 3, 4
Platinum	**700** **—**	**537** **—**	**—** **150**	**200** **—**	**380** **—**	**1,817** **—**	**—** **150**	**1,967**	**1, 3**
Manganese	— 400	1,059 204	— —	— —	— —	1,059 —	— 604	1,663	3, 4
Tantalum	**—** **—**	**—** **—**	**—** **—**	**1,100** **—**	**—** **500**	**1,100** **—**	**—** **500**	**1,600**	**4**
Tungsten	— —	527 230	— 200	— —	340 —	867 —	— 430	1,297	3
Iron ore	**—** **—**	**840** **—**	**—** **280**	**—** **—**	**—** **—**	**840** **—**	**—** **280**	**1,120**	**3**
Beryllium	75 100	— —	— —	— —	— —	75 —	— 100	175	2
Gold	**—** **—**	**142** **—**	**—** **—**	**—** **—**	**—** **—**	**142** **—**	**—** **—**	**142**	**3**
Vanadium	— —	125 —	— —	— —	— —	125 —	— —	125	3
Direct **Related** **Totals**	**9,648** **13,960** **23,608**	**10,258** **2,523** **12,781**	**560** **1,850** **2,410**	**28,010** **3,060** **31,070**	**1,585** **2,400** **3,985**	**50,061** **—**	**—** **23,793**	**73,854**	

'NOTES Funds may be attributed to more than one goal, where appropriate, upper amounts "direct" program funding for research primarily to Indicated category, lower amounts "'related" program funding directed to the categories, but with significant potential for impact in the indicated category,

†1 Department of Energy
2 Department of Defense
3 Department of the Interior
4 Department of Commerce
5 National Aeronautics and Space Administration.

SOURCE U S Department of Commerce, Survey *Materials Life Cycle Research and Development in the Federal Government Fiscal* Year 7980 (N BSIR 81-2359 DOE, September 1981) The above table may not reflect all Federal funding of research that affect strategic materials For example, Department of Defense support for surface modification technologies, near. net shape technologies, and retirement for cause research are not identified in the substitution and conservation columns of the table These programs could result in savings of chromium, cobalt, nickel and other strategic materials.

for the coordination of Federal materials and minerals R&D activities, directing:

- Assistant Secretary-level representation from the departments and agencies concerned with minerals and materials;
- the incorporation into COMAT of the Department of Defense Material Availability Steering Committee and the Interagency Materials Group;
- establishment of a working panel within COMAT to coordinate Federal R&D on essential materials;
- establishment of a formal mechanism within COMAT for information exchange among agency managers of materials R&D programs; and
- policy resolution of materials R&D questions through the Cabinet Council on Natural Resources and Environment.

Table 8-6.— Distribution of Critical Materials R&D Funding by Stage of the Materials Cycle* ($1000)

	Exploration of resources	Extraction	Processing raw materials	Manufacture and fabrication	Application and utilization	Evaluation of properties	Development of materials	Waste management	Totals
Chromium	151 —	- —	550 —	10,300 420	60,050 100	15,570 —	31,616 300	260 70	118,492 890
Aluminum	121 —	— —	1,555 —	1,000 —	3,000 —	5,000 —	500 —	— —	11,176 —
Niobium	32 —	— —	180 —	2,000 200	3,000 200	1,000 500	4,000 —	— 70	10,212 920
Cobalt	120 30	306 106	825 381	810 420	1,000 113	1,190 100	1,270 530	397 84	5,918 1,764
Titanium	51 —	— —	250 210	300 200	1,000 200	1,000 500	1,050 300	— —	3,651 1,410
Platinum	38 —	 —	500 —	200 —	500 —	1,000 —	680 —	— 150	2,918 150
Manganese	55 30	251 106	50 124	500 —	600 113	1,000 —	300 —	247 288	3,003 661
Nickel	120 30	251 243	660 324	— 200	— 313	500 500	860 230	397 293	2,788 2,133
Lead	92 —	— —	950 —	-1 —	- —	— —	— —	265 —	1,307 —
Tantalum	 —	 —	— —	100 200	200 200	500 500	200 	 —	1,000 900
Iron ore	— —	· —	840 —	 —	— —	— —	— —	— 280	640 280
Tungsten	57 —	— 	470 430	— —	 —	— —	125 —	— 	652 430
Direct Related	837 90	808 455	6,830 1,469	15,210 1,640	69,350 1,239	26,760 2,100	40,601 1,360	1,566 1,235	101,962 9,588

*NOTES Funds may be attributed to more than one goal, where appropriate, upper amounts direct program funding for research primarily to indicated category lower amounts related program funding directed to the categories, but with significant otential for impact in the indicated category

SOURCE U S Department of Commerce *Survey iterials Life Cycle* Research *and Development i the Federal Government Fiscal Year 1980* (N BSIR 81 2359 DOE, September 1981)

COMAT was directed to perform an inventory of Federal research and technology activities that would be useful for interagency coordination and for assessing national materials needs and objectives. The data acquired from this inventory would be used by the Cabinet Council to aid in policy decisions pertaining to R&D.

COMAT's report, "Inventory of Federal Materials Research and Technology, " was issued in June 1983.[13] Unlike the survey done for fiscal year 1980, funding levels for strategic materials research are not separately addressed or even identified. Nor does the 1983 report group Federal R&D activities by specific material (e. g., cobalt, chromium) or by program objective (e.g., minerals development, recycling). Instead, the 1983 inventory lists overall materials program funding levels for fiscal year 1982 and estimated expenditures for fiscal year 1983 on an agency-by-agency basis. Since the 1983 inventory does not identify strategic materials research activities, it is of virtually no use as a policy tool in the development of material-specific objectives and policies for R&D.

Moreover, COMAT apparently has not taken action to assure that individual agencies keep track of strategic materials research activities on an agencywide basis, COMAT representatives from several Federal agencies were con-

[13] Federal Coordinating Council for Science, Engineering, and Technology Committee on Materials, *Inventory of Federal Materials Research and Technology: Fiscal Year 1982* (Washington, DC: Executive Office of the President, Office of Science and Technology Policy, June 1983).

tacted by OTA to determine whether detailed agencywide information on strategic materials funding had been compiled independently for fiscal year 1985. Some agencies provided this information at a relatively detailed level, but one major department was able to provide only a partial answer. In this case, OTA was told that it would take 3 to 6 months to perform a strategic material R&D inventory if given a formal request.

It would appear, therefore, that COMAT has not established an effective mechanism to track and report on interagency strategic materials research activities, The need for such information in R&D policy formulation is widely recognized as a key step in establishing effective coordination of all Federal activities related to strategic materials research, In fact, the 1984 National Critical Materials Act calls on the Executive Director of the National Critical Materials Council to catalog, "as fully as possible, research and development activities of the Government, private industry, and public and private institutions" (Public Law 98-373, sec. 209(a)(3)). Such information will indeed be critical if the Council is to effectively exercise its new responsibility for coordination and review of Federal strategic materials activities. Consistent with the premise that the executive branch should have considerable flexibility in formulating materials programs and plans, the Act does not specify a timetable for such catalog activities nor identify its content.

Certainly, if effective coordination of strategic materials research were envisioned, information equivalent in detail to the earlier (fiscal year 1980) survey would be needed. Periodic surveys of this sort would also be needed to develop a multi-year executive branch plan of action for strategic materials. Given the recent difficulties the executive branch has had in developing such survey information, congressional oversight and guidance may be needed if the initial activities of the Council do not give priority to developing a continuing tracking system of this sort (table ***8-4,*** issue ***2).***

Mineral Production and Processing

Currently, there is virtually no production of cobalt, chromium, manganese, or PGMs from domestic mines.[14] However, prospects are good for platinum and palladium production from the Stillwater Complex in Montana, which could provide about 10 percent of U.S. PGM needs (as a percentage of 1982 consumption) if prices increase somewhat, as well as much larger amounts of PGM if it becomes feasible to open other sites, (The decision whether to go ahead with an initial mining project is expected to be made in 1985,) In addition, more than 10 million pounds per year of cobalt **(5,000** short tons) could be provided for a 10- to 15-year period if known domestic cobalt deposits were simultaneously developed, production will not occur unless cobalt prices rise and are sustained at appreciably higher levels than is now the case, or unless the government provides a substantial subsidy. Domestic prospects for production of chromium and manganese production are not good, owing to the very poor quality of known domestic deposits.

The United States heavily relies on a few countries for its supplies of strategic materials, To some extent, supply diversity could be broadened through greater reliance on other countries which have known deposits of strategic materials. Of the four metals under study, supply diversity is currently greatest for manganese; greater diversity on manganese supplies will probably depend on the willingness of producers in Australia, Mexico, and Brazil

[14]About 2 percent of apparent domestic consumption of manganese is contributed from manganiferious ore containing less than 35 percent manganese, Platinum group metals have been produced domestically in small amounts as recently as 1982. Larger amounts of manganese and some chromium were produced during the 1940s witb considerable Federal subsidy. Substantial amounts of cobalt were produced under Federal subsidy during the 1950s. Cobalt was also produced in small amounts as a byproduct of iron production until 1971.

to increase production for export markets. In the case of chromium, expanded production in Turkey, Albania, and the Philippines appears to be the primary near-term supply diversification option; in the longer term, limited amounts of chromite may be obtainable from deposit types that are now untapped in the Philippines and New Caledonia. Increased supplies of cobalt maybe obtainable from Canada as a byproduct of nickel-copper production. Over the long term, cobalt may be obtained as a byproduct from Pacific-rim nickel laterite deposits when future nickel demand justifies new mine operations. Other than the U.S. Stillwater deposit, significant diversification of platinum supplies seems unlikely. (See table 5-3 of ch. 5 for a country-by-country ranking of supply diversification prospects for each of the first-tier minerals.)

OTA's analysis of alternative policy actions with regard to minerals production and processing focused on the following areas: potential of intensified exploration assistance to locate new domestic deposits; possible government subsidization of domestic production; targeting of Federal programs to encourage diversification of foreign supply sources; and options for addressing problems associated with declining domestic processing capabilities. The options addressed are summarized in table 8-7 and discussed below.

The emphasis in this assessment is on technological issues. Therefore, political issues associated with competing values for Federal land management are not addressed here. Some Federal lands are under highly restrictive management policies which limit the circumstances and kind of exploration activities that can be undertaken, and these restrictions are seen by some exploration geologists as possibly inhibiting private initiatives to discover new mineral deposits. In general, Federal lands being considered for permanent addition to such restrictive management systems as the National Wilderness Preservation System are given some mineral appraisal prior to designation. The reader is referred to a prior OTA assessment,[15] in which alternative alternative management strategies and policy issues associated with mineral development on Federal lands were comprehensively addressed, as well as several other, more recent publications addressing mineral development issues and Federal lands.[16]

Exploration for Domestic Strategic Resources

The outlook for the discovery of commercial-scale deposits of the first-tier strategic materials in the United States is generally agreed to be insufficient to generate more than minor interest by most mineral developers. The U.S. Government spent considerable effort during and after World War II in seeking high-grade domestic deposits of manganese and chromium, with only subeconomic deposits to show for its efforts. Cobalt, while not sought directly, has only been found in low grades and only as a result of exploration for nickel, copper, lead, and zinc. Platinum, the one successful case of discovery of a commercial-grade deposit of a first-tier material, is quite limited in terms of total U.S. demand for PGMs.

Past failures, however, do not mean that there is no possibility of discovering domestic deposits of chromium, cobalt, manganese, or PGMs. Past experience, however, makes exploration less attractive for these materials than

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[15] U. s. Congress, Office of Technology Assessment, *Management of Fuel and Nonfuel Minerals in Federal Lands*, OTA-M-88 (Washington, DC: U.S. Government Printing Office, April 1979).

[16] Legislative status of selected bills in the 98th Congress relating to strategic minerals evaluation and Federal lands is provided in *Strategic Materials Management,* June 15, 1984. Procedures used in regional mineral appraisals on Federal lands are discussed in John J. Schanz and John G. Ellis, *Assessing the Mineral Potential of the Federal Public Lands* (Washington, DC: U.S. Library of Congress, Congressional Research Service, 1983). Recent Department of Interior activities related to Federal land mineral evaluation potential are discussed in U.S. Department of the Interior, *Summary Report: US. Bureau of Mines Department of Interior Programs and Studies Required by the National Materials and Minerals Policy Act of 1980 (Public La w 96479)* (report submitted to the chairman of the Subcommittee on Transportation, Aviation, and Materials, U.S. House of Representatives Committee on Science and Technology, with cover letter dated Nov. 10, 1983).

Table 8-7.—Policy Alternatives for Exploration, Mineral Production, and Processing

		Arguments for/against	
Problem/issue	Option	Positive	Negative
1. Lack of industry interest in exploring for domestic deposits of strategic materials.	a. Improve the economics of domestic deposits of strategic material resources through tax incentives for exploration and development.	Cost to government arises only if deposits of strategic materials are developed. Costs are limited to tax liability of those deposits.	Tax incentives can only improve project economics by several percentage points. They cannot turn deposits similar to known domestic chromium, cobalt, and manganese deposits into profitable ventures.
	b. Reduce the cost of exploration by increasing level of detail obtained by government resource assessments and by conducting R&D to improve exploration technology.	Could reduce cost of identifying areas of possible deposits and allow industry to conduct more exploration within current exploration budgets.	Actions are not material-specific and are unlikely to result in increases in exploration for strategic resources unless coordinated with other incentives.
	c. Improve ability to predict location of possible deposits of strategic material resources through increased understanding of ore formation processes.	Could lead to location of deposits that cannot be found by current exploration equipment or methods.	Unlikely to result in discovery of any deposits of strategic materials resources until greater scientific understanding is achieved—a process that could take many years.
2. Known domestic strategic material sources are economically noncompetitive, and therefore not currently producing.	Federal subsidies for domestic mining.	Assure domestic supply. Reduce likelihood of disruption occurrence.	High costs relative to purchasing for stockpile on world markets. No guarantee that production period would coincide with any supply disruption.
	a. Cobalt	Could provide an assured domestic supply of up to 10 million pounds per year over 10 to 15 years.	At 1983-84 metal prices, a substantial Federal subsidy would be needed so that it would be cheaper to buy cobalt on world markets for the National Defense Stockpile.
	b. PGM	A relatively small subsidy could assure near-term production of 6 to 10 percent of U.S. needs.	Government action probably not necessary. Market forces alone are expected to promote domestic production — possibly in the next 5 years.
	c. Chromium and manganese	Subsidy would assure production of Cr and Mn in limited amounts over relatively short time period; might encourage domestic exploration activities.	Uneconomic nature of known deposits would require high subsidies: for Cr, two or more times and Mn, seven times market world prices.
3. Magnitude of production resources of existing concentrated foreign suppliers inhibit development of alternate sources.	Use government resources to expand foreign production of strategic materials.	Reduces likelihood of successful supply disruptions.	Perpetuates reliance on foreign sources. If actions are not targeted, option could promote competition for nonstrategic domestic mining industry.
	a. Improve information about possible projects.	Relatively inexpensive use of resources.	Results tend to be limited and difficult to foresee.
	b. Reduce political risks to U.S. private sector investment.	Relatively inexpensive use of resources.	Targeting to specific minerals is difficult. Results are limited in weak mineral markets.
	c. International direct/indirect aid to encourage foreign projects.	While relatively expensive, many foreign mining projects are marginally economic and could be less costly than domestic subsidies. Aid can be coupled with other developing country needs.	As with domestic subsidies, it would be less expensive at current prices to purchase from existing sources for stockpile.

Table 8-7.—Policy Alternatives for Exploration, Mineral Production, and Processing (Continued)

		Arguments for/against	
Problem	Option	Positive	Negative
4 Declining domestic ferroalloy ore processing capability	a Government subsidies to maintain/develop capacity along with ore sources	Assures processing capability in time of emergency need.	Creates excess global supply.
	b Government support for modernization efforts and R&D in emerging technologies.	Improves productivity and therefore competitive position of domestic Industry. Could target development of flexible production capacity,	Closure of some remaining facilities continues with job loss in near term.

SOURCE Office of Technology Assessment

for other minerals, such as copper, lead, zinc, or bauxite, for which there is a substantial record of success to hearten investors.

The Federal Government generally participates in only the first of the four stages of prospecting and exploration, that of wide-scale reconnaissance (table 5-2, ch. 5). Information obtained at this stage helps prospectors select areas for more detailed survey but is unlikely to locate signs of a specific deposit. In view of the prevailing industry belief that commercially competitive deposits of the first-tier strategic materials are unlikely to be discovered, an increase in general information would probably be insufficient in and of itself to encourage more intensive exploration for these specific materials, although such information may indeed encourage exploration for other metals.

To increase the potential for discovery of domestic deposits of first-tier materials, the potential profitability of deposits must increase, the cost of exploration must decrease, or the likelihood of success of exploration must increase. Further, in order to be efficient in the use of Federal resources, actions directed toward these goals should be material-specific. Table 8-7, issue 1, identifies three approaches which could be taken.

The first possibility, increase of profitability of potential deposits, could be approached through tax policy (e.g., increasing the percentage depletion allowance for specified materials), through exploration loans that have reduced rates or reduced principal when they lead to the discovery of deposits that eventually lead to commercial exploitation, and through mining and metallurgy R&D directed specifically at reducing the cost of exploiting deposits for the first-tier materials as they are likely to be found in the United States.

The second approach would be for the Federal Government to undertake, either directly or through contract with private firms, more detailed prospecting activities, again directed at specific types of mineral deposits. This approach could also include the development of improved exploration equipment and techniques, such as the development of geophysical techniques for locating sedimentary manganese deposits, more portable and accurate equipment for geochemical analysis, and lower cost core-drilling equipment.

The third approach, increasing the likelihood of success of exploration, could combine current data collection and analysis procedures with intensified research into the processes of formation of deposits of strategic materials, with the goal of improving the ability to identify areas most likely to have deposits of specific first-tier strategic materials. Predictive geology, based on theories of the formation of mineral deposits, is in its infancy and certainly a long-term approach to strategic materials supply issues.

Domestic Production of Strategic Materials

As discussed in chapter 5, known domestic deposits of first-tier strategic materials cannot support profitable minerals production at current prices, Nonetheless, domestic production could make a contribution to domestic material supplies. Of the materials under study, potential contributions to material supplies (as a portion of U.S. requirements) varies from moderate to large in the case of PGMs and cobalt to small, in the case of chromium and manganese,

Several potentially exploitable PGM deposits exist, the largest of which are located in the Stillwater Complex in Montana. Commercial production of PGMs from one site in the Complex is now under evaluation by a private firm. Other than monitoring progress at the Stillwater site, there appears to be no pressing need for government involvement in this project at this time. It has been estimated that, if a decision to go ahead is reached, about 2 years lead time would be necessary before the mine would produce PGMs. At current prices, domestic production of the other first-tier materials would require a Federal subsidy.

The Federal Government can subsidize—and sometimes has subsidized—domestic production of strategic materials. During World War 11 and the Korean war, the United States was able to obtain some of its chromium, manganese, and cobalt supplies through heavy subsidization of production from limited domestic deposits. Between 1948 and 1962, about 14 million pounds of cobalt were produced domestically under Federal subsidy.[17] When Federal contracts expired, most domestic production ceased.[18]

Recent concern about strategic materials has rekindled interest in domestic production subsidies through Title III of the Defense Production Act (table 8-7, issue 2). Title III provides several instruments (loans, loan guarantees, guaranteed prices, or purchase commitments) that could be used to support industrial processing and production of strategic materials.

Possible subsidization of domestic cobalt production was among an initial list of Administration projects proposed for possible Title III assistance during congressional debate about reauthorization of DPA for fiscal years 1985 and 1986. In hearings about this legislation, the U.S. General Accounting Office expressed concern that the Administration had not undertaken adequate cost/benefit comparisons among candidate Title III projects for which it sought funding. In April 1984, Congress amended DPA to authorize a total of $100 million in financial aid to defense industrial projects for fiscal years 1985 and 1986.[19] The amendment did not preclude a Title III cobalt project, However, it did establish new procedures for the Administration to follow in seeking Title III authorization. Except in times of a national emergency, Title III projects must be presidentially cleared, and a determination made that the alternative is the most practical means for meeting a shortfall.

It is not clear whether the Administration has any plans to initiate a cobalt project, but the issue of domestic production of strategic materials is likely to continue to be debated in the future,

Potentially exploitable cobalt deposits in the United States include the Blackbird Mine in Idaho, the Madison Mine in Missouri, the Gasquet Mountain Project in California, and the Duluth Gabbro Complex in Minnesota. For domestic production to occur without subsidy, cobalt market prices, about $6 per pound in 1983 and $11 to $12 in mid-1984, would need to rise appreciably and be sustained for a protracted period in order for mine owners to assume the risks of production, Each of these sites has received some scrutiny for possible subsidy under the Defense Production Act. Although DPA can be used to secure materials for the stockpile, it has generally been used to support industrial processing capabilities considered essential for national defense, One proposed method of subsidy has been a "contingent purchase contract" between the government and mine owner. In such contracts, a negotiated "floor price" would be set with the company. The government would be obli-

[17] James C. Burrows, *Cobalt: An Industry Analysis,* a Charles Rivers Associates Research Study (Lexington, MA: Heath Lexington Books, 1971), p. 111.

[18] Some cobalt continued to be produced at Pennsylvania's Cornwall Mine until 1971 as a byproduct of iron ore production without subsidy.

[19] Public Law 98-265, the Defense Production Amendments Act of 1984, was signed into law by President Reagan on Apr. 17, 1984.

gated to buy the cobalt only if the company were unable to sell it on the open market,

Some evaluation of production economics from candidate sites has been conducted by the sponsoring companies, with estimates ranging from $16 to $25 per pound. However, some of the estimates have not been revised since 1981, and none should be considered definitive, According to the Department of Defense, "contradictory data being quoted and evaluated" led the Air Force, in 1983, to seek "definitive data through legal contracting procedure for a cost/benefit analysis of domestic cobalt production."[20] The form of the Air Force effort, a draft request for proposal,[21] evoked controversy because some believed that a final determination had been made to go ahead with a pilot plant project to evaluate the quality of domestically produced cobalt for defense applications. The effort did not reach the stage in which such definitive data was submitted, however.

The Blackbird Mine (an inactive mine which produced cobalt under DPA subsidy in prior years) is considered the largest potential domestic source. In 1981, the company which owns the mine estimated that Blackbird could support an annual production level of 3.7 million pounds (1,850 short tons) of cobalt for a 14-year period if cobalt prices rose and were sustained at a $20 per pound level or if the government subsidized production. [22] Lead time for production would be 3 to 4 years. A spokesman for the company recently told OTA that it now estimates a sustained cobalt price of $16 per pound to be sufficient to bring the mine into production, owing to discovery of higher grade cobalt at the site, and improved mine planning, It has also increased its mine life estimate to 20 years.

Another inactive mine, the Madison Mine in Missouri, could also support production of cobalt as a primary ore, according to its proponents. Closed since 1961, Madison produced lead, copper, and nickel, and during the 1950s, cobalt under a DPA subsidy. Madison's owner estimates that the mine could produce 2 million pounds of cobalt annually over an estimated mine life of 20 years. In addition, substantial amounts of cobalt are present in mine tailings that have accumulated over the years from lead and zinc mining in the area. These tailings could provide 300,000 to 500,000 pounds of cobalt annually, using prevailing lead and zinc recovery technologies, but far more if other processes were adopted. The Madison mine owner estimated in 1981 that a cobalt price of $25 per pound would be necessary to bring the mine into production. Revised estimates apparently have not been made since then.

The Gasquet Mountain Project, a proposed mine on National Forest land in California, would involve production of cobalt and some chromite as coproducts of nickel production. A 1981 feasibility study for the project estimated that the lateritic deposits at the site could support annual production of 19.4 million pounds of nickel, 2 million pounds of cobalt, and 50,000 tons of chromite over an estimated mine life of 18 years. The economic feasibility of the project would thus depend on multiple metals prices, with changes in the relative value of one metal, compared to the others, affecting production economics. For example, if nickel prices were $3.50 per pound, cobalt production would be viable at $12.50 per pound. If nickel prices rose to $3.96 per pound, cobalt would be viable at $8 per pound, but if nickel prices were $2.21 per pound, a cobalt price of $25 would be required.[23] Nickel prices in 1983 were $2.20 per pound. A company

[20] Department of Defense submittal entitled "General DoD Comments on the Classifed GAO Statement, " in U.S. Senate Committee on Banking, Housing, and Urban Affairs, *Reextension of the Defense Production Act,* hearing held Sept. 15, 1983, (Washington, DC: U.S. Government Printing Office, 1983), p. 161.

[21] Department of the Air Force, Draft Request for Proposal (DFRP) for Contemplated RFP F33615-83-R-5106: Establishment of Domestic Cobalt Production, Aug. 30, 1983.

[22] Letter of R.V. Fiorini, Vice-president, General Manager, Noranda Mining Inc. to Senator Harrison S. Schmidt as reproduced in U.S. Senate Committee on Banking, Housing, and Urban Affairs, Defense Production Act and the Domestic Production of Cobalt Hearing, Oct. 26, 1981, Senate Hearing 97-38 (Washington, DC: U.S. Government Printing Office] p. 143,

[23] Documents provided to OTA on the Gasquet Mountain Strategic Metals Project by the California Nickel Corp. in March 1983. The figures cited above assume a constant chromite price of $40 per ton.

spokesman told OTA that it had not revised its economic evaluation since 1981.

In assessing the desirability of subsidizing domestic cobalt or any other strategic material, several considerations should be kept in mind. Supply security is the primary argument used in support of government assistance for domestic cobalt production. To some, the risks entailed in continuing to depend on insecure foreign sources of cobalt is an overwhelming argument in favor of a domestic production subsidy even when cobalt could be more cheaply acquired from world markets for the stockpile. The supply security aspect of domestic production is most persuasive if the risk that a protracted supply disruption will occur before adequate quantities of cobalt could be acquired for the stockpile is seen as unacceptable. To those who think the short-term risks of a supply disruption are not great, stockpiling now, rather than depleting limited domestic cobalt reserves, seems to provide greater supply security in the long term.

Fluctuating cobalt or coproduct metal prices have made it difficult to identify the extent of subsidy that would be needed, compared to simply buying cobalt on the world markets for the National Defense Stockpile. If 1980 cobalt prices ($25 per pound) were to return and be sustained, domestic production of cobalt would compare favorably with world prices, and thus could be cost effective even with minimal government involvement. At 1983 cobalt prices, about $6 per pound, it would cost the government three to four times as much to buy cobalt from domestic mines than from the world market. If it is assumed that mid-1984 cobalt prices (about $12 a pound) will continue, stockpiling from world markets would still be cheaper than subsidizing domestic production.

Environmental considerations may also delay or potentially curtail proposed projects, especially when supply security objectives are not widely perceived as a pressing need. Concerns about possible water pollution and environmental damage to California's Gasquet Mountain were raised in the legislative debate about the 1984 DPA amendments.[24] The Blackbird Mine is surrounded by Federal lands, including 40,000 acres which has been classified as wilderness with a stipulation that it will remain open for cobalt exploration and mining activities. Although open, actual development of the mine could be delayed by the process of establishing Federal regulations governing access to the site across Federal lands. Water pollution problems arising from the presence of arsenic will have to be overcome before production can begin.

Encouraging Foreign Production of Strategic Materials

The United States is likely to be dependent on a few producing countries for most of its supplies of strategic materials for the foreseeable future. Actions can be taken to increase the number of countries supplying these materials, thus achieving greater diversity of supplies. However, these actions take time to implement and are not likely to alter fundamentally the supply patterns in the next decade. Over the long term, a concerted effort to promote diversity of foreign supply sources of specific minerals could help reduce overall U.S. vulnerability to a supply disruption. To be most effective, these actions must be narrowly focused to address problems that are mineral-specific and to avoid possible competition with efforts to develop domestic sources.

Potential benefits of supply diversification strategies will vary by material, Of the first-tier materials, for instance, prospects for supply diversification appear to be best for manganese, which already has the most diverse supply. Several alternative supply sources also exist for chromium, such as expanding output in Turkey and the Philippines. Cobalt diversification, primarily in the Southwest Pacific, depends to a large degree on world markets for nickel and copper, since cobalt is usually a by-

[24]Environmental concerns associated with Gasquet Mountain were discussed in House debate on the conference report on the DPA amendments. *(Congressional Record, H2538,* Apr. 17, 1984.)

product of production of these metals. In the case of PGMs, the most promising known but nonproducing deposit is in the United States. Outside the United States prospects for PGM supply diversification will depend on new discoveries rather than on the development of known deposits.

The likelihood that a supply diversification strategy will succeed also depends in part on the extent to which the Federal Government and U.S. industry are willing to accept the risks and attendant costs associated with bringing alternative supply sources on line, According to a 1982 GAO report, direct investment by U.S. firms in mining and smelting activities in developing countries has fallen significantly since the late 1960's and early 1970s.[25] Reasons for this include prolonged weak markets, perceived risks associated with such investments (due to political uncertainties), and controls on investment asserted by producer countries. On the other hand, the involvement of multinational mining firms in developing countries is still extensive, While equity participation has declined, firms are willingly supplying technology and management services.

New mining ventures from exploration to production can cost $1 billion and more. Moreover, mining prospects are long-term ventures. Exploration activities to discover new deposits can take many years and are often unsuccessful. Once a deposit is identified and found to be promising, a minimum of 2 to 5 years is required to bring a new mine into production; somewhat less time is required to increase output from an existing alternative mine that is already in operation. Hence, actions taken to promote diversity of supplies must be planned and executed far in advance and are not likely to be successful as a way to avert immediately the consequences of a supply disruption, Even if financial obstacles were overcome, supply diversification strategies have inherent risks. Near the end of World War II, and through much of the 1950s, the Federal Government supported development of Cuban nickel resources to diversify U.S. supplies. The effort was successful in developing Cuban nickel, but for political reasons the United States has not had access to this supply since the early days of the Castro regime.

In some countries the government plays a very active role in backing international resource projects launched by private firms. In Japan, for instance, overseas ventures of sufficient importance to be considered "national projects" are backed by low-interest loans to both the country in which the project is located and the consortium of Japanese firms involved in the project. The government itself serves as the major stockholder in the consortium. Among industrialized nations, Japan is unusual in that half or more of its foreign mining and smelting investments are in developing countries—as compared to 25 percent among U.S. firms.[28]

In the United States, private industry—not government—plays the primary role in securing mineral supplies from foreign sources, and this policy is likely to continue. However, the Federal Government can be a catalyst in promoting private investment overseas, through the dissemination of essential information, by facilitating interaction between private industry and foreign owners, and by the targeting of international aid to private and producer country mining activities that are related to strategic materials. The extent and degree of encouragement considered appropriate can range from modest to extensive, depending on the importance given to supply diversification in overall U.S. strategies to reduce import dependency.

The Reagan Administration has emphasized information development to encourage private action. Initiatives include a Department of Interior minerals training program for State Department regional resource officers to improve the collection of information. It also includes discussions with market economy countries about mineral investment problems and the

[25] U.S. General Accounting office, *Federal Encouragement of Mining Investment in Developing Countries for Strategic and Critical Minerals Has Only Been Marginally Effective* (Washington, DC: [J. S. General Accounting Office, 1982].

[28] Ibid., p. 5.

need for more consistent statistical reporting. In fiscal year 1983, the U.S. Geological Survey (USGS), in cooperation with Canada, West Germany, Australia, South Africa, and Great Britain, began an International Strategic Mineral Inventory program to upgrade and standardize resource and production information about world deposits of chromium, nickel, manganese, and phosphate. Other minerals are expected to be added to the inventory. The USGS Office of International Geology obtains funding through the Agency for International Development (AID) for various mineral potential studies of developing nations. These projects are often cooperatively funded by the developing nation, must be "sold" to AID on the basis of their assistance to immediate development needs, and do not necessarily focus on strategic materials. (Phosphate for agricultural purposes is a major item.)

President Reagan has also given new responsibilities to the Trade and Development Program (TDP) of the International Development Cooperation Agency (IDCA) in order to "broaden opportunities for the U.S. private sector to participate in the development of and diversification of foreign sources of supply of strategic materials."[27] The mineral resources group of TDP received funding of about $700,000 in fiscal year 1984 which is supplemented by cooperative funding for specific projects. TDP concentrates its efforts on a small number of strategic minerals and, as of March 1984, had issued five reports that identified investment possibilities in those minerals for U.S. mining companies in foreign countries.[28] TDP also brings private project promoters and prospective investors together informally to discuss foreign mining and processing projects. The TDP reports have been thoroughly prepared and are potentially useful; however, some industry people claim they provide information already available and that the analysis is not extensive enough to attract private investment, especially during periods of depressed minerals markets.

One TDP report has resulted in a TDP followup contract for a feasibility study to further encourage private industry's involvement. Future reports might be more useful if they included possible followup steps for government action to be considered by relevant agencies (e.g., technical or financial assistance), and joint venture opportunities for the private sector. Although TDP's approach is promising, funding levels may be too low to realize any substantial improvement in diversified minerals sources.

Other Administration efforts have involved the development of a model bilateral investment treaty. When adopted by individual countries, such a treaty may improve a country's investment climate, but does not necessarily create mineral investment opportunities,

An alternative or complementary approach would be to target or give special priority to strategic materials in U.S. bilateral assistance programs, or as part of U.S. responses to multilateral assistance in which it participates (table 8-7, issue 3). The 1980 National Materials and Minerals Policy, Research and Development Act emphasized the importance of such activities by calling on the President to "assess the opportunities for the United States to promote cooperative multilateral and bilateral agreements for materials development in foreign nations for the purpose of increasing the reliability of mineral supplies to the Nations."[29] Major multilateral and bilateral programs applicable to mineral development are highlighted in box 8-A.

Multilateral programs, established by the United Nations, the World Bank group, and other international organizations, have been the primary means (albeit indirect) for U.S. assistance for mining and smelting activities in developing countries. These programs, according to the GAO report, have had a limited impact on increasing supplies of strategic materials of importance to the United States. Of 45 mineral-related projects during 1971-80, most involved copper, lead, zinc, and iron ore,

[27] *National Materials and Minerals Program Plan and Report to Congress,* op. cit., p. 11.

[28] Reports cover manganese in Mexico, cobalt in Morocco and Peru, and chromium in Turkey and the Philippines.

[29] Sec. 4(g) of Public Law 96-479.

Box 8-A—Bilateral and Multilateral Assistance Approaches for Mining Investment in Other Countries

Bilateral Approaches:

- ***Overseas Private Investment Corporation (OPIC)*** was established in 1969 to facilitate flow of private U.S. capital and skills to the Third World through insurance, financial guarantee, direct loan, and promotional programs. Mining and energy initiatives were instituted in 1977 to help revive investor interest in developing country mining projects. Although OPIC does not support a significantly large number of projects, the mining projects that it does support are generally targeted to strategic minerals.
- ***Export-Import Bank*** was created in 1934 to provide financial support for U.S. export sales through direct loans, financial guarantees to private lenders, and commercial and political risk insurance. Unlike most assistance programs, Ex-Im operations are not limited to developing countries. Programs were directed toward specific mineral needs during World War II and the Korean war using the Reconstruction Finance Corporation and the Defense Production Act as sources of funding. Since then, however, lending (for mining equipment exports) has been limited and has not focused on strategic minerals. The Bank has no control over the mix of incoming applications it processes. Weak markets and inability to compete effectively with foreign counterparts have resulted in only a few mineral projects.

Multilateral Approaches:

- ***Development Banks (e.g.,*** the **World Bank, Asian Development Bank, and Inter-American Development Bank) tend to devote small shares of their overall funding to mineral projects and have no mechanism to target** "U. S." **strategic materials when the strategic materials of other involved nations are different. Priorities for addressing basic needs of people limit mineral projects** to those which are viewed as a way to improve foreign exchange earnings and balance of payments postures. Development bank activities sometimes conflict with U.S. domestic mining interests by promoting the development of foreign competition.
- ***U.N. Revolving Fund for Natural Resources Exploration*** was set up in 1973 to help increase natural resources exploration in developing countries and expand the world's known resources base. Its mission is to address what experts perceive to be the greatest mining-related problem for developing countries: insufficient exploration. While exploration costs generally are not great compared with mine development costs, the risks are greater due to a lower probability of success. Therefore, funding is difficult to obtain–even from development banks. The Fund, which contracts actual work to the private sector, deals in exploration projects exclusively although it does have the authority to do follow-up feasibility studies. Of 11 projects completed in 1983 and 5 continuing on through 1984, none involved first-tier strategic materials. According to GAO, by 1982 the Fund had not yet demonstrated its capabilities convincingly, having had financial and initial problems in convincing governments to use its services, and in obtaining contributions to set up the fund.
- ***International insurance plans*** to safeguard foreign investment have been proposed but never implemented, due to lack of agreement on how to arbitrate disputes, negotiate claims, finance the plans, or distribute voting rights. Recent proposals and sponsors include: International Investment Insurance Agency (1966), World Bank; International Resources Bank (1975), U.S. Government; Inter-American Fund for Energy and Minerals (1979), Inter-American Development Bank.

and only four involved strategic materials. Multilateral programs that support exploration activities, such as the U.N. Revolving Fund for Natural Resources Exploration, have some potential to result in new discoveries of strategic materials.

Several bilateral aid programs could be specifically targeted to encourage U.S. firms to invest in mining activities for strategic materials, Past efforts have been only marginally successful, as was brought out by the GAO report, Among other things, the report found that existing programs were not oriented toward providing solutions to what are, after all, mineral-specific problems (the TDP studies, a notable exception, were only beginning at the time of the GAO study) and that there was a lack of coherent investment strategies to guide implementation actions over the long term.

One of the often stated impediments to mining firm investment abroad is the fear of political instability, A mining firm will launch a project only if it believes that the project will yield an adequate after-tax return on equity over a specified time period. Political risk insurance can reduce the political component of economic decisionmaking. The Overseas Private Investment Corporation (OPIC), established by Congress in 1969, provides such insurance as well as financing (loans and loan guarantees) to U.S. firms investing in developing countries. Its involvement in mineral projects, however, has been limited due to the weakness of markets and, in the area of natural resources, it concentrates on energy projects. OPIC, like the Export-Import Bank (see box 8-A), assists rather than subsidizes foreign projects. Thus, it can improve the competitive posture of U.S. firms but not the markets wherein firms must operate.

GAO cited policy and procedural restraints on OPIC's activities as limiting factors on the number and type of mineral projects it supports. As a public corporation, OPIC must assure that, overall, its investments generate a positive return. To do so, its investments are broadly based in terms of industries and countries served. Loans granted by OPIC are restricted by legislation to small businesses, which disqualifies the majority of mining firms. Loan guarantees (up to $50 million) are available only for the production phase of mining projects. OPIC political risk insurance maximum ($125 million) may not be consistent with the real costs of most mineral investment activities today, although it does provide 20-year coverage of the entire mineral exploitation process from exploration through production.

The President's materials plan does not address foreign aid or loans as an instrument of national minerals policy. When more limited means do not encourage the diversification of sources, it may—given the perception of risk—be appropriate for the Federal Government to engage in direct financing support for exploitation of, or creation of demand for, these diversified sources. Stockpile needs and other Federal Government purchases, for example, could be directed at creating demand for unexploited strategic materials deposits. Loans and loan guarantees could assist countries both directly and indirectly in exploiting mineral resources. For instance, prospective mining projects are often located inland, without adequate in-place transportation and energy infrastructure. Developmental aid for such supporting projects could overcome economic obstacles to mine development, provide investment opportunities for U.S. firms, and, at the same time, stimulate the overall economic growth of a developing nation.

In using both multilateral and bilateral mechanisms, a clear distinction must be made between the needs of the domestic mining industry and those of U.S. firms involved in the international mining industry, Policies developed for one may be viewed as detrimental by the other. The domestic mining industry today faces increasing competitive pressure from foreign mining that is supported by governments that are more concerned with generating foreign exchange or jobs than with profits. Many of these ventures may be supported either directly or indirectly by public sector international development banks. The domestic industry, which is guided by the principles of the free market, says it cannot continue to compete in global markets under these newly emerging and unfamiliar rules of competition. Conversely, U.S. firms involved in foreign mining projects can take advantage of them. Clearly, for commodities where domestic mining competes with foreign mining, a policy choice must be made that serves both sectors or just one. Fortunately, inherent in the nature of "strategic materials" is the fact that little, if any, domestic mining occurs for these commodities at present. If policies are specifically targeted, they would have less chance of being detrimental to the domestic mining industry and greater likelihood of success in diversifying U.S. supply sources.

Implications of Diversification of Supply for Ferroalloy Production

Diversification of ore suppliers offers only a partial solution for decreasing the potential for interruption of supplies of chromium and manganese, Since the bulk of chromium and manganese ore is processed into ferroalloys for use in the production of steel, stainless steel, and superalloys, it is also necessary to ensure that ferroalloy production facilities will be available to process ore obtained from a variety of suppliers.

The domestic ferroalloy industry was once the major supplier of ferroalloys to the U.S. steel industry, but this position has been eroded by foreign suppliers such as South Africa, France, and Brazil. This decline can be attributed largely to nontechnical factors, particularly:

- policies by foreign governments and international organizations that provide financial incentives that encourage development and operation of ferroalloy production in developing countries, primarily in conjunction with operating mines;
- higher cost for U.S. labor in comparison to labor costs in other producing countries;
- current exchange rates that, due to the strong U.S. dollar, favor the use of imported products over domestic production; and
- higher capital investment required of domestic producers in order to meet stringent U.S. environmental and safety requirements.

The domestic ferroalloy industry has a number of strengths, including large, in-place capacity for production of ferroalloys; adaptability of furnaces between various manganese, chromium, and silicon products (although conversion between products is, in some cases, limited by design of electrical or pollution control systems) and proximity to markets for ferroalloy products that allows quick response to special orders for nonstandard products.

One way to assure ferroalloy processing availability would be to encourage the construction of processing capacity along with chromium and manganese mines, but this method would provide excess worldwide capacity and be wasteful of capital investment. A second alternative is to maintain a ferroalloy processing capability in the United States, one designed to be flexible both in products (ferrochromium, ferromanganese, silicon, and ferrosilicon, and specialty products such as calcium silicon) and in production rates (with plants designed for rapid expansion of capacity).

New technology may change the outlook for the domestic ferroalloy industry in two ways. First, process improvements, such as increased use of automated equipment and computer control, may increase labor productivity, reduce energy consumption, and raise the quality of products. These improvements, in turn, would improve U.S. competitiveness, since high labor and energy costs are a contributor to the high cost of domestic production, and the quality of products for specialty steels and superalloy can protect and strengthen the U.S. position in these markets. The second major technical change facing the industry is the adoption of plasma arc and high-voltage electric furnaces. These advanced furnaces, which are in the latter stages of development and the first stages of commercial use, may offer lower operating costs and improved energy efficiency over the submerged arc furnaces now in use. However, they must be built to replace furnaces now in use, which will require the industry to make major capital investments. These new furnaces are applicable both to domestic and to foreign production, so it is possible that the domestic industry could be left behind its foreign competition if it is slow to adopt the new processes.

Since the immediate problems of the ferroalloy industry arise from political and economic factors rather than technical ones, the principal response of the government (if it is to respond) is likely to be political, In the longer term, however, there are more options (table 8-7, issue 4). First, the Bureau of Mines can work with industry to develop process improvements, particularly in the area of automation and computer control, that increase labor productivity and reduce energy and material consumption. Second, financial incentives, such as increased depreciation, tax credits, or low-interest government loans could be used to encourage the adoption of new ferroalloy furnaces. Third, the government could use its influence in international lending organizations to encourage the use of development loans for projects other than ferroalloy facilities. Fourth, additional support, either as loans or grants, could be provided to the ferroalloy industry to include in plant designs the potential to increase capacity or shift between products rapidly when supplies of imported ferroalloys are unavailable and ores must be processed for domestic industries.

Substitution and Advanced Materials

In discussing substitution, it is useful to differentiate between two broad classes of alternative materials: *direct substitutes,* i.e., materials that, while not necessarily preferred, could replace materials now in use; and *advanced materials,* which may displace currently used materials in time because the new material offers a clear advantage in performance, cost, or other benefit. In contrast to direct substitutes, which may require only minor design changes for use, advanced materials often require redesign of products for optimal use.

Direct substitutes are immediately available for many applications that now use first-tier strategic materials. However, this is not the case for some applications that are most critical to the national defense and the U.S. economy. As discussed in chapter 7, the Federal Government sponsors considerable R&D aimed at finding direct substitutes for strategic materials, Much of the research has focused on development of lower chromium alloys as potential replacements for stainless steels of high-chromium content, and on alternative jet engine superalloy which contain reduced amounts of cobalt or other strategic materials. This research adds to the choices of materials available to designers. However, institutional and economic barriers impede acceptance of these materials so that many will not be fully developed. Substitutes used in highly demanding applications need to undergo extensive testing and qualification before they can be used. Industry has little incentive to undertake this testing unless the substitute offers a clear advantage over currently used materials.

Besides direct substitutes for materials now used, the Federal Government also plays a primary role in sponsoring research on advanced materials, such as advanced ceramics and composites, and rapidly solidified metals. These materials have long-term promise to change current requirements for strategic materials—although to what extent is difficult to predict due to the need for redesign of product components. In some applications, net savings in strategic materials may occur, while in other applications, product redesign could lead to increased use of strategic materials.

Many barriers must be overcome before use of these advanced materials becomes widespread. Some barriers are technical, arising from the materials themselves or from the need to improve current processing techniques so that reliability is increased. Others are institutional and economic. Some of these materials are much more expensive than currently used materials, although costs may go down in time as processing problems are overcome. From the institutional side, widespread use of these materials may have to await establishment of standards and specifications for their use, as well as greater emphasis on these materials in engineering curricula.

An emerging import vulnerability issue concerns adequacy of domestic processing and manufacturing capabilities for advanced materials. Most advanced materials are made from raw materials which are plentiful in this country. However, the manufacturing capabilities (including technology and technical know-how) to produce qualified materials suitable for the most demanding applications is distributed among several nations. Most advanced materials are in limited production status at this time. As they become more frequently used, the extent to which the United States should attempt to become self-sufficient in all stages of production of these materials is likely to be increasingly debated.[30]

Table 8-8 shows selected policy alternatives with respect to substitution and advanced materials. Although some policy issues associated with direct substitutes and advanced materials are held in common, there is enough divergence to merit separate discussion, as is done below.

Direct Substitution Options

The Federal Government is the primary sponsor of R&D on direct substitutes for strategic materials. Except in times of a supply shortage, industry has little incentive to conduct such activities unless the substitutes afford a clear benefit of cost or performance.

Emphasis on substitution research among Federal agencies has accelerated since the mid-1970s. Several Federal agencies, including various defense agencies, NASA, the Bureau of Mines, and the DOE national laboratories undertake or sponsor strategic materials substitution research. Despite recent budget cutbacks, Federal funds available for substitution research appear to be quite healthy, with some gains and losses among different Federal agencies. The Bureau of Mines substitution research effort has increased recently, while NASA's Conservation of Strategic Aerospace Materials (COSAM) program has been cut somewhat. The COSAM program has resulted in some superalloys with reduced cobalt content that have the potential to directly replace existing superalloy. These materials have not received extensive development beyond the laboratory stage. A more fundamental purpose of the COSAM program was to sponsor *basic* research that would shed light on the function that strategic materials play in superalloys. (Table 8-5 shows total U.S. expenditures for substitution on specific strategic materials for fiscal year 1980, the last year in which governmentwide data is available.)

Federal sponsorship of substitution research is generally conceded to be essential if research programs are to be undertaken on a sustained basis to find direct substitutes for strategic materials. However, this research alone will not do much to reduce overall vulnerability unless promising substitutes are developed to the point that they can be used by industry. The time lag between initial laboratory development of an alternative material and the stage in which it is ready to be used is often protracted; many expensive and time-consuming intermediary steps must be surmounted before the material can be considered "on the shelf." The extent to which the Federal Government needs to be involved in narrowing this gap depends on the relative weight that is given to substitution in an overall strategy to reduce import vulnerability.

Actions the Federal Government could take, besides its continuing important role as the primary sponsor of research on substitutes, are identified in table 8-8 and discussed below.

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[30] For a discussion of initial self-sufficiency issues associated with the advanced composites industry, see Stanley L. Chamon, *Industrial Base and Qualification of Composite Materials and Structures (An Executive Overview)* (Arlington, VA: Institute for Defense Analyses, 1984). Concern about U.S. reliance on foreign sources and a sole domestic supplier for polyacrylonitrile (PAN), used in production of some carbon composites, was one issue discussed in the legislative debate about reauthorization of the Defense Production Act in 1984.

Table 8-8.—Policy Alternatives for Substitution and Advanced Materials

Problem/issue	Option	Arguments for/against: Positive	Arguments for/against: Negative
Direct substitution:			
1. Information about available substitutes which would entail less use of strategic materials may be difficult for small firms to obtain, hence delaying their ability to respond to a supply disruption and possibly impeding initiative to ease import dependency in advance of supply difficulties.	Sponsor a substitution information program to disseminate information to industry, giving private sector (testing societies, trade associations, universities, and industry) key roles in designing and implementing the program so that it is of maximum utility to end users. Option appears most promising as a means to reduce chromium overspecification in stainless steel.	Would enhance U.S. substitution readiness—especially in the case of chromium, for which major opportunities to conserve chromium in nonessential application exists; would provide "continuing visibility" for strategic material concerns by setting up an institutional program to disseminate information.	Information could become obsolete quickly; industrial users may not have as great a problem in obtaining such information as is sometimes contended (i.e., industry would have a great incentive to find this information in the event of a supply difficulty).
2. Work on promising laboratory substitutes that could reduce strategic material requirements is often ended at an early stage because of lack of industry incentives to develop these materials on their own, and because Federal agency research funds may not be provided for the long period of time needed to develop substitutes fully for commercial use.	Sponsor a joint government-industry effort to develop selected promising substitutes to the point where they can be commercially used, focusing on lower chromium alloys that could reduce chromium requirements for stainless steel.	Could result in long-term reduction in import vulnerability if substitutes were successfully developed so that they could be used by industry; Federal sponsorship of applied research to develop direct substitutes may not be justified unless more substitutes are developed to the point where they could be commercially used.	Long-term nature of commitment, plus the expense of developing particular alloy substitutes may mean that other options (e.g., diversification of supplies and recycling) would be more useful. Government has limited experience with alloy development and should leave development to industry alone.
Advanced materials:			
3. Problems in coordinating advanced materials R&D at the executive branch level have long been apparent. The new National Federal program for advanced materials R&D, established by the National Critical Materials Act of 1984 (Public Law 98-373) is intended to overcome this difficulty. The flexibility given to the executive branch in formulating this program, could lead to innovative approaches, but a danger also exists that congressional intent will be misconstrued.	Exercise oversight functions on the Administration's Federal program plan for advanced materials R&D, to establish early and continuing guidance to the National Critical Materials Council and other implementing agencies about program direction, goals, and specific initiatives.	Would help the administration establish goals for Federal activities with respect to advanced materials; would give greater visibility to advanced materials in the executive branch, Congress, and the country as a whole.	Oversight process, if taken to an extreme, could lead to a disproportionate expenditure of EOP staff resources on meeting congressional information demands, which would be contrary to the intent of Public Law 98-373 as expressed in its legislative history.
4. Advanced materials use may be impeded by lack of qualified engineers, designers, and material scientists trained in the use of these materials.	Provide startup education and curriculum development grants to U.S. universities to expand faculty and to stimulate research and graduate/undergraduate programs in advanced material studies and in design with these materials.	May help U.S. maintain competitiveness of its advanced material industries through research and training of personnel needed to establish domestic capabilities.	Industries that stand to benefit from such educational activities should assume primary responsibility for meeting their technology and personnel needs through contributors to educational institutions.
5. Widespread adoption of advanced materials may require development of more uniform testing methods, material specifications, and procedures for certification and qualification than currently exists, as well as an improved and updated data base to facilitate use of advanced materials.	Sponsor initial activities in conjunction with testing societies, industry, and academia and relevant Federal agencies to develop guidelines and data requirements for testing methods, specifications, procedures, and design with advanced materials.	May encourage more widespread use of advanced materials by providing greater certainty to material producers and consumers about conditions in which they can be appropriately used.	Government should not attempt to "force" premature uniformity on a developing technology. Evolution of needed information systems can best be accomplished incrementally by users and suppliers as the need arises.

SOURCE: Off Ice of Technology Assessment.

These actions are of two kinds: greater government involvement in developing the information needed to facilitate industry use of new materials; and greater Federal support for the post-laboratory development of direct substitutes.

Providing Substitution Information to Industry

Many on-the-shelf technologies and materials could lower strategic materials consumption in the United States, and potential substitutes are at various stages of development. These alternative materials and technologies are well known to defense industries, automakers, and other large or technologically advanced industries. However, many small or technically unsophisticated firms ordinarily would not have easy access to information about specific materials, technologies, and applications in which substitution could lessen strategic materials use. Difficulties in obtaining information about alternative materials might lengthen their substitution response time in a supply disruption—a critical concern, especially for firms that are not likely to receive an allocation preference in the event of a supply disruption of major proportions,

The need for a more effective mechanism for collecting and transferring information about strategic materials substitutes to industry and end users has long been recognized by the materials community (table 8-8, issue 1). Several major conferences on materials, as well as various testing societies and industry organizations, have recommended that a substitution information program of one sort or another be an essential component of strategic materials policy.[31] Some steps have been taken by government agencies, trade organizations, and professional organizations to improve substitution information availability, but these have been conducted on an ad hoc basis without a sustained focus.

Information programs of varying scope and complexity have been proposed. At the most basic level, an ongoing program of conferences, seminars, and information dissemination has generally been seen by the materials community as a relatively inexpensive and effective way to heighten industry awareness of research developments relevant to strategic materials substitution and conservation opportunities. Many Federal agencies and private organizations have contributed to such programs in the past, but a continuing program of this sort does not exist.

Others see a need for a national information repository for substitution studies, including studies on alternative materials, analyses of alternative processing techniques, substitution case histories, and directories of experts on particular technologies or material substitutes. Much of this information may be available through individual agencies or through the National Technical Information Service (NTIS), which has been given augmented responsibilities by the Reagan Administration to transfer information about Federal technology development to the private sector. But the demands placed on NTIS may be too diffuse to address effectively the particular issue of strategic materials substitution.

At a more ambitious level, various organizations and individuals have proposed establishment of a "substitution information stockpile" to provide engineers, designers, and procurement officials with highly technical information needed to make decisions about available substitutes. As generally proposed, this "information stockpile" would identify, systematize, and compile detailed information about the properties and potential applications for currently available and qualified alternative materials. Often, systematized information about alternative processing and fabrication technologies that could conserve strategic *materials* is seen as an essential component of the information stockpile. The primary purpose of such a stockpile would be to reduce response time

[31] The importance of substitution information is illustrated in recommendations made at a workshop on conservation and substitution for critical materials held in 1981 at Vanderbilt University under sponsorship by the Departments of Commerce and the Interior. of 27 recommendations, 10 involved development, compilation, and dissemination of information related to substitution, conservation, and displacement of critical metals,

in a supply disruption. However, it is possible that more firms would adopt their own contingency strategies for reducing their dependency on imported materials if they were aware of available substitution opportunities.

Even though often proposed, specific steps toward development of an information stockpile have been limited. Part of the reason for this may be that developing a proper format for the information—a technical handbook or computerized data bank that could be available to industry—could be quite difficult. Safeguards, for example, would have to be built into the system to assure that the information, however presented, clearly delineates those applications in which qualification is required from those in which it is not, Another reason may be a concern that a handbook or data bank could quickly become obsolete, presenting stale information of little value. Hence, revision and updating of the information stockpile would be essential. Finally, testing societies and trade associations have limited resources available for such purposes, while the Federal Government has focused most of its substitution effort on research.

Although some components of an information program—conferences and library repository, for example—have broad relevance to strategic materials, the substitution bank concept would probably be of greatest practical use for chromium—especially as used in stainless steel. Designers frequently overspecify (use higher chromium content stainless steels than may be needed) in many noncritical applications. Stainless steel is used in a wide variety of applications throughout the economy; an estimated 60 percent of this demand is for applications in which adequate substitutes are available, or in which some substitutes maybe developed after a period of R&D. Ready access to information about these substitutes could help the consumer of chromium for nonessential uses to respond to a supply disruption and ease problems the government might have in allocating available chromium to essential uses.

Initial work on chromium substitution options includes a major report by the National Materials Advisory Board and an industry survey by the Metal Properties Council, which is an active supporter of the substitution bank concept. (This latter effort has been supported in part by NBS.) In this regard, it should be noted that a nonprofit entity, called the National Materials Property Data Network, Inc., has recently been established to explore ways for providing computerized data on engineering materials.[32] Additional work to define the feasibility and parameters of an information stockpile would be needed.

Development of a substitution information program would require extensive interaction between government and the private sector, including participation of testing societies, trade associations, professional societies, and industry. This need for extensive private sector involvement in development and use of the information program may mean that the government's key role would be sponsorship—not actual conduct—of the program. For example, the government could provide funds to a testing society, a university, or other nonprofit organization, to establish a nonprofit center with a specific mission and charter to develop information about substitute materials and new technologies that would help conserve strategic materials. Participation of key Federal agencies, such as national laboratories, NASA, NBS, the Bureau of Mines, and the Department of Defense could be structured into the center's charter.

Developing Substitute Alloys

As a general proposition, the Federal Government's role in developing substitute materials often ends at an early stage of laboratory research. Research results may be published, but it is usually left to private industry to decide whether additional development steps should be taken. Thus, many strategic material substitutes are not placed on the shelf by federally sponsored research, nor are they likely to be fully developed by industry unless the

[32] See National Materials Advisory Board, *Materials Properties Data Management Approaches to a Critical National Need* (Washington, DC: National Academy Press, 1983), NMAB–405, for a discussion of the need for upgrading U.S. materials properties data bases.

new material is seen as providing significant cost or performance benefits compared to currently used materials.

Substitute materials used in critical applications, such as in powerplants and chemical plant processing, must be extensively tested after their initial development in the laboratory, Depending on the application, it can take 5 to 10 years and several million dollars to develop and qualify new materials or processes to the point that they can be used by industry,

Many—perhaps most—of the direct substitutes that have been developed with Federal funds would be more expensive (at current prices) than the materials they would replace. A few are potentially cost competitive with currently used materials and thus might be used by industry if the qualification hurdle were overcome.

Given this situation, the question arises as to what steps, if any, could be taken by the Federal Government to bring potential substitutes closer to commercial use? One alternative would be for government to support a cooperative effort with the private sector to select, fully test, and qualify (where necessary) a few materials with significant potential to reduce critical material needs (table 8-8, issue 2). Most of this effort would probably involve contracts with industry, testing societies, and universities to carry out key roles, Once these materials were fully developed, they would be available for use by industry or could serve as a kind of standby "national emergency alloy system, " analogous to the national emergency steel system developed in World War II.

Such a step would not necessarily entail a major new Federal program: it could be accomplished through selective targeting of strategic materials development activities to focus on those materials considered to be most critical to U.S. substitution preparedness. Both the Defense Production Act and the Stockpile Revision Act authorize the President to develop substitutes for strategic and critical materials. Federal agencies, such as the Department of Defense, Bureau of Mines, and NASA, from time to time sponsor test heats and other development activities of substitute materials on a cooperative basis with industry. Moreover, the Federal Government has sometimes sponsored new materials for qualification by testing societies, Oak Ridge National Laboratory is now sponsoring a 9 percent chromium steel for use in powerplants, for example,[33] and the Department of Defense has played a key role in the commercialization of many materials considered essential for defense purposes.

Obviously, because many substitutes are potential candidates for augmented development activities, considerable care would be needed in selecting the materials. Selection of any materials for further development work would depend on many considerations, including their technical prospects, degree of industry interest, and potential contribution to reducing import vulnerability relative to other strategies (e.g., stockpiling or recycling).

For example, as discussed in detail in chapter 7, several superalloy with reduced cobalt content, intended as direct replacements for superalloys now used in jet engines, are now under development, These will not be available for use unless they undergo several years of additional testing. It has sometimes been proposed that steps be taken to prequalify such low-cobalt substitutes (presumably by government) so that they would be available for use.[34] Because of rapid changes in materials used in jet engines, these substitutes could be partially obsolete by the time they are fully developed. Therefore, other options—ranging from stock-

[33]This steel was not developed to reduce import vulnerability, but as part of the breeder reactor program. It is intended to replace both a 2¼ percent chromium steel and a 18 percent chromium steel now used in powerplants, so that the design of a particular powerplant will determine whether more or less chromium is used. It has been speculated that this steel may eventually replace 18 percent chromium stainless steels in some other applications, although, to date, this has not occurred. Federal expenditures in data development and other activities associated with qualification of the material are estimated to be about $5 million since 1978. An estimated $2 million in private services have been donated to the effort. The 9 percent chromium alloy is expected to be used commercially in some applications in 1984.

[34]See, for example, the discussion in U.S. Department of Commerce, *Conservation and Substitution Technology for Critical Materials: Proceedings of Public Workshops,* June 15-17, 1981, p. RI-1.

piling to recycling to aggressive pursuit of advanced materials—could be more effective in reducing vulnerability in this application.

Fewer options are available for reducing chromium import vulnerability for stainless steel, however, and despite appreciable research efforts, an estimated 40 percent of the chromium used in stainless steel is considered irreplaceable. At present, several low-chromium alloys that could substitute for higher chromium stainless steels in some applications are in the early stages of laboratory development. (Table 7-4 in ch. 7 shows selected examples.) Current substitution research is addressing applications in the midrange of difficulty (technically feasible substitutes could be developed after a period of intensive R&D). Full development of substitutes for this midrange of applications could ease allocation decisions in a supply disruption so that available chromium could be used in those applications for which no alternatives are likely to be available,

Targeting a few of the most promising low-chromium substitutes for augmented development would require in-depth analysis of their current status, needed development steps and associated costs, and applications in which they could reduce critical and strategic material needs. Substantial input from industry, testing societies, and academic institutions would be needed both to identify the most promising materials, and to undertake most of the indicated development steps, Given the costs that could be entailed—the Oak Ridge qualification process discussed above cost an average of $1 million per year over a 5-year period—such a program would have to be conducted at a small scale, with no more than two or three materials undergoing augmented development at any given time.

Ultimately, whether it would be desirable to establish a cooperative government and industry program of this sort depends on the prominence that is assigned to substitution in overall Federal strategies for reducing import dependency. Development of direct substitutes is a medium-term (5 to 15 years) response for reducing import dependency, so that actions taken now will not have an immediate effect. At the same time, it maybe difficult to justify Federal applied research on direct substitutes unless the end result is to reduce overall U.S. import vulnerability. This may not occur unless ways are found to develop promising substitutes to the point to which they can be used by industry.

The Potential of Advanced Materials

Strategic materials displacement is not a primary reason for the current interest in advanced ceramics, various composite materials, rapidly solidified alloys, and other advanced materials that are the subject of intensive R&D efforts by government and industry. Rather, these materials promise special performance benefits compared to currently used materials. However, advanced materials usually contain little or no cobalt, chromium, manganese, or PGMs, and therefore, over the long term they have promise to displace or reduce some strategic material requirements. Often, reduced strategic material requirements will be an indirect benefit of using these materials. Since redesign of component systems may be necessary for optimal use of advanced materials, overall savings in strategic materials are difficult to predict.

Advanced materials—unlike direct substitutes for currently used materials—have the potential to provide the basis for important new U.S. industries, while at the same time reducing requirements for strategic materials in some applications. Advanced ceramics may become a multibillion dollar business, with potential markets projected to reach over $20 billion by the year 2000, However, at present, the competitive posture of the United States in advanced ceramics lags behind Japan in the area of electronic components, and the United States is in some danger of losing the race for market supremacy in engineering ceramics, Other countries, including Great Britain and some Western European countries, are also vying for expanding world markets.

A 1984 Commerce Department study of the advanced ceramics industry indicated that neither the United States nor Japan was in the clear lead with regard to advanced ceramic engineering materials. However, the Department predicted that the United States could fall behind Japan if current trends continue. Japanese success was noted in the following areas:

- domination of electronic components made of advanced ceramics;
- domination of supplies of advanced ceramic powders;
- greater and more organized R&D efforts;
- superior performance/cost characteristics of Japanese demonstration products;
- reputation for accepting short-term losses and investing in long-term product-market development; and
- record in developing and implementing superior commercial manufacturing processes and technologies.[35]

The potential importance of an internationally competitive advanced materials industry to the U.S. economy, and the stance of the Federal Government in encouraging such industrial activities, is likely to be an increasingly visible issue in the years to come. In general, the alternative roles that the government could play in fostering a strong domestic ceramics industry are likely to be identified and debated within the broader context of the overall posture of government-industry relations, not in the context of strategic material issues. Regardless of the extent of government involvement in encouraging U.S. competitiveness in this area, a number of technical and institutional problems will have to be overcome before these materials come into general use. Therefore, the discussion here is focused on issues of Federal involvement in research, development, information transfer, and education, rather than on the full spectrum of alternative policies to encourage advancement of this sector of the economy.[36]

[35] U.S. Department of Commerce, *A Competitive Assessment of the U.S. Advanced Ceramics industry* [Springfield, VA: National Technical Information Service, 1984), p. 64.

[36] Readers who are interested in alternative Federal roles in strengthening the international competitiveness of the U.S. advanced ceramics industry are referred to the Commerce Department's assessment identified in the previous footnote. The broader issues associated with alternative government actions involving transfer of new technologies to the private sector are discussed in "Development and Diffusion of Commercial Technologies: Should the Federal Government Redefine Its Role?" (Office of Technology Assessment Staff Memorandum, Industry, Technology and Employment Program, March 1984.)

Government Support of Research and Development

It is generally thought that the United States leads the world in basic research with regard to advanced materials. Funding of advanced materials R&D activities in the United States appears to be generally healthy. However, continuation of a strong basic research effort will probably be needed for many years. Manufacturing processes and fabrication technologies are areas in which more emphasis in R&D is generally considered necessary. The high costs of fabricating composites, for example, arises in part from labor-intensive and time-consuming processes. In advanced ceramics, key needs are to improve powder production and to develop reliable processing technologies to produce flaw-free ceramics economically. Improved nondestructive evaluation techniques are critically needed in both composite and ceramic applications.

As with other areas of material research, several Federal agencies, including NASA, NBS, the Bureau of Mines, various Defense Department agencies, and the DOE national laboratories, undertake or sponsor advanced materials research. Much of the government research is undertaken on a contractual basis with industry. Information sharing among researchers, including various government agencies and those firms directly involved in R&D, is generally considered by researchers to be effective. However, coordination of policy with respect to advanced materials, particularly at high levels of the executive branch and with Congress, has been fragmented.

As discussed previously, the National Critical Materials Act of 1984 calls for the establishment of a "national Federal program for advanced materials research and development," giving key responsibility to the National Critical Materials Council in the Executive Office of the President for implementing the program, The Council, among other things, is directed to prepare and annually review a Federal program plan for advanced materials R&D. The plan is to designate key responsibilities for carrying out research, and is to provide coordination with the Office of Management and Budget, the Office of Science and Technology Policy, and other appropriate Federal offices and agencies,

The Council is also to review annually the materials research, development, and technology budget requests of all Federal agencies to ensure close coordination of the goals and directions of such programs with policies determined by the council, The Office of Management and Budget, upon reviewing individual agency budget requests, is to consider them as an "integrated, coherent, multiagency request" to be reviewed by the Council and OMB for adherence to the national Federal materials program plan for each fiscal year.

The process established by the 1984 Act can be expected to give far greater visibility to research needs associated with advanced materials than has existed heretofor. However, in keeping with the process orientation of most congressional laws pertaining to materials R&D, the law gives the Council considerable discretion in putting together components of the plan. For example, while the law makes it clear that the program is to include R&D from "basic phenomena" through processing and manufacturing, it does not define the term "advanced materials, " thus giving the Council flexibility in determining which classes of materials fall under the program plan, The Council will also have discretion in determining overall goals and objectives of such a plan. As a result, congressional oversight and guidance may be needed to determine whether the Council's program accurately reflects Congress' intent in establishing the program (table 8-8, issue 3).

Education Needs and Advanced Materials

Considerable concern exists about the adequacy of current engineering curricula and training of engineers and designers in the use of advanced materials, Most curricula in engineering schools are designed to familiarize engineers with materials that are most prevalently used ***today,*** such as metals. Progress in advanced materials fields—the materials which will come into greater prominence in the future—may hinge in part on the success of engineering curricula to make engineers and designers familiar with processing technologies, and product design associated with advanced materials, Although many U.S. universities are important research centers in one or more advanced material areas, U.S. universities are turning out comparatively few people in some advanced materials fields. In the area of ceramics, for example, only 36 identifiable doctorates were estimated to have been granted in the 1982-83 school year by U.S. universities.

The Federal Government can assist U.S. universities to increase their emphasis on advanced materials if it so desires, Various assistance programs administered by the National Science Foundation, and academic research and curriculum development activities supported by other Federal agencies could be used to channel increased support for advanced materials activities in universities,

One option would be to provide initial educational development grants to several universities for a specified time period (e.g., 5 years), after which time the university would assume full responsibility for the program. Because these programs could have clear benefits to private industry, industry might contribute to such an effort. The startup funds could be used to attract new faculty, support research, assist in acquisition of needed instruments, or participate in other activities that would be needed to establish a sound curriculum and research program, Industry-university cooperation and coordination could be encouraged through advisory committees comprised of industry and government representatives and through internships and collaborative research projects,

Transfer and Diffusion of Advanced Materials Technologies

Advanced materials are currently in an early stage of commercial application. A key issue in their ultimate acceptance and adoption by industry on a widespread basis will be the extent to which reliable engineering data (including clearly defined procedures for testing materials), materials specifications and physical property data, and standards can be developed in a form that is readily accessible to users.

As discussed in chapter 7, current U.S. problems in maintaining an upgraded materials property data management system in general are acute. In the case of many advanced materials, including rapidly solidified metals, ceramics and some composites, absence of accessible information is a major constraint to their widespread use, Data on advanced materials is held largely by the research community and by the few firms that have been integrally involved in their early development or that have proprietary data for specialized applications. A kind of catch-22 is involved in this situation: designers will not use new materials until they have data on their behavior in engineering applications, but until the materials are used by designers, that data will not exist.

The formal codes, reliability standards, specifications, and other forms of information that would aid product design engineers select materials are not generally available for advanced materials. Development of such information will be a long-term process, and it may be many years before general agreement is reached about the proper form of such information.

Although testing societies, private industry, and trade associations, generally determine material standards, the Federal Government can play an important facilitating role if it chooses, Several Federal agencies, including the Department of Defense, DOE, NBS, and NASA all have important programs related to advanced materials, and have been integrally involved in maintaining materials data bases that could be of considerable relevance to standard-setting activities.

A cooperative effort by government and industry to undertake initial work to develop organizing concepts, define information needs, and identify appropriate formats for needed engineering data could be an important preliminary step toward advanced material standard-setting. Such a cooperative endeavor would require extensive interactions between testing societies, industry, academia, and government, with each contributing key inputs to the process. One possible arrangement (table 8-8, issue 4) for facilitating such interaction would be for the Federal Government to partially sponsor (with contributions by relevant industries) a nonprofit center associated with a testing society, a university, or other nonprofit institution. A similar approach is being used to explore the feasibility of establishing a national materials properties data network with primary reference to metals.

Conservation and Recycling of Strategic Materials

OTA's analysis indicates that ongoing trends in industry have led to more efficient use of materials in processing and manufacturing. These trends are expected to continue as firms upgrade facilities and adopt new manufacturing processes.

In steelmaking, for example, manganese requirements for each ton of steel produced are expected to be reduced from 36 to 25 pounds by the year 2000. Somewhat greater savings (in terms of imported manganese) are likely because of increased use of scrap and improved manganese recovery rates. Near-net shaping processes used in the aerospace industry will also reduce cobalt raw material requirements for superalloy production, although this will also be accompanied by a reduction of home and prompt industrial scrap preferred for recycling. The incentive to conserve PGMs is very high, owing to their high cost; thus, improvements in catalyst design that would reduce PGM use can be expected to be adopted quickly. Some modest improvements in chromium utilization can be expected, but the rapid phase-in of the argon-oxygen decarburization (AOD) process in making stainless steel is now nearly complete, and no major breakthroughs appear imminent. As a rule, material-conserving technologies will be adopted because of product quality and cost competitiveness reasons, not because of concern about strategic materials.

Important opportunities also exist to increase supplies of cobalt, chromium and PGMs through recycling. In the case of PGMs, the chief opportunity for increased secondary production is through recycling of automotive catalysts; an emerging industry structure is developing to collect and process these catalysts. Opportunities to extend cobalt supplies include improved recycling of cobalt values from obsolete superalloy scrap and recovery of cobalt from spent catalysts used by the petroleum industry. Although stainless steelmaker now derive one-fourth of their chromium needs from purchased scrap, losses from three areas—downgrading, failure to recover obsolete scrap, and losses of chromium in steelmaking wastes—are substantial. See table 6-6 in chapter 6 for a detailed listing of recycling opportunities.

Increased recycling not only augments strategic material supplies, but also has environmental benefits associated with reduced landfilling and disposal of wastes, Recycling also offers energy conservation benefits, since scrap already embodies initial energy requirements needed to process raw ores into concentrated form, Energy savings from recycling aluminum scrap, compared to manufacturing the same product from virgin materials, can exceed 90 percent, and for copper, iron and steel, lead, and zinc, savings of over 60 percent have been noted.[37] Because the first-tier minerals covered by this report are produced and often partially processed abroad, net energy savings to the U.S. from increased recycling of these materials would only accrue as an alternative to increased domestic production, however.

[37] National Association of Recycling Industries, *Recycled Metals in the 1980s* (New York: National Association of Recycling Industries, 1982), p. 174.

Economic barriers (arising from the added cost of collecting, sorting, transporting, and reprocessing obsolete scrap and waste) and institutional impediments (e.g., difficulties in organizing collection systems and the reluctance of consumers to use recycled materials) are the major constraints on recycling.

Appreciable advances in recycling technologies have been made in recent decades, owing in part to Bureau of Mines' R&D efforts, and industry initiatives. In general, few technical problems need to be overcome to increase recycling of PGMs, cobalt, and chromium. However, in some applications—especially superalloys—advanced technologies may have to be developed before major advances can be made in current levels of recycling, Increasing complexity in materials used in products in general also means that continuing R&D will be needed to meet future recycling needs,

OTA's analysis of recycling issues focused on several areas of possible congressional concern: adequacy of information about current and prospective levels of recycling; the need for evaluation of the indirect effects of Federal programs and policies on recycling in order to identify possible changes that could facilitate recycling; and the possible need of a pilot plant project to demonstrate advanced superalloy recycling technologies. These issues, and associated options, are summarized in table 8-9 and discussed below,

Information Needs and Recycling

Recycling's potential to reduce import dependency can only be roughly estimated unless reliable information is available about both current levels of recycling nationwide and about quantities of unrecovered scrap and waste that could potentially be recycled if economic or technical conditions changed. Current statistical series provide incomplete information about annual levels of recycling because they focus on the purchased component of scrap supplies, and do not estimate potentially recyclable materials that are not recovered. Increased emphasis on compilation of recycling data and trend analysis seems needed if policymakers are to have a realistic picture of the prospective role that recycling could play in reducing U.S. dependency on imported materials (table 8-9, issue 1).

From time to time, agencies such as the Bureau of Mines and the National Materials Advisory Board have produced relatively comprehensive materials flow models for individual metals or applications. These models have appreciably increased understanding of overall recycling levels, but have been prepared infrequently, with little or no followup or consistency in procedures used. The need for materials flow information is especially apparent in the area of superalloy recycling—an area that changes rapidly, affects use of several strategic materials, and is of obvious importance to national security. Most current information about the flow of superalloy scrap is based on conditions in 1976—the last year for which a comprehensive materials flow model for superalloy scrap was prepared by the government. Efforts to update this model using 1980 data—but 1976 scrap ratios–do not fully reflect the important changes that have occurred in superalloy recycling since then.

Analysis of long-term trends in conservation and recycling is also needed on a periodic basis, especially since the two often influence each other in complex ways, Adoption of near-net shape technologies by aerospace manufacturers will reduce the amount of preferred scrap generated in the fabrication of superalloy parts. This means that obsolete scrap and lower quality manufacturing scrap will comprise an increasing portion of the materials potentially available for recycling. Similarly, efforts such as the Air Force retirement-for-cause program to extend the life cycle of jet engine parts could reduce the amount of obsolete scrap available

Table 8-9.—Policy Alternatives for Recycling Strategic Materials

		Arguments for/against	
Problem/issue	Option	Positive	Negative
1. Annual statistical series do not provide an adequate picture of current and prospective recycling levels; detailed information is out of data and not prepared on a regular schedule.	Supplement current data with in-depth "cradle-to-grave" data and analysis of Cr, Co, Mn, and PGM or other materials as appropriate on a regular schedule.	Better information about recycling is needed for realistic appraisal of recycling's prospective role in reducing import dependency.	Could add to industry paperwork requirements
2. Adjustments in Federal programs and policies could encourage greater recycling of strategic materials, but the necessary evaluation of these programs has not been done by the Administration.	Call for an executive branch evaluation, with recommendations to Congress, about ways to structure Federal programs related to taxation, real property procurement and disposal, environmental regulations, etc., to encourage strategic materials recycling.	Could lead to eventual changes in Federal programs which would be helpful to recycling firms in increasing recycling levels.	Federal Government should not attempt to favor one mineral form over another; overemphasis on recycling could inhibit domestic mining activities related to strategic materials.
3. Advanced recycling technologies for superalloy may not be developed by private industry because of low metal prices.	Authorize one or more pilot-plant projects to demonstrate technical feasibility of reclaiming individual elements from superalloy scrap or other advanced scrap recovery processes.	If technical merit of research processes is demonstrated in pilot project, it may be possible to recycle most of the superalloy scrap that is now downgraded or lost. (An estimated 2.8 million pounds of cobalt was lost in superalloy scrap alone in 1980.)	Option provides less immediate supply security than domestic production and depends on successful outcome of pilot project to determine commercial feasibility; government should not be involved in commercialization of new technologies.

SOURCE. Off Ice of Technology Assessment for recycling. These interrelationships are discussed in greater detail in chapter 6.

Superalloy applications are not the only area where current data are inadequate for identifying current and prospective recycling levels. opportunities for recovering more chromium from obsolete stainless steel products and steelmaking wastes can only be roughly estimated since most of the available national data date from 1976 and 1974, respectively. Important improvements have occurred since then. Similarly, monitoring of PGM recycling from automotive catalysts and electronic scrap will clearly have to be emphasized in the years to come in order to develop accurate information about recycling trends in this industry.

Analysis of industry trends and the revision of scrap material flows on an annual basis is probably not necessary or desirable, but it would be desirable on a periodic basis, perhaps once every 4 or 5 years. The Bureau of Mines, which sponsored the superalloy analysis discussed above as well as a similar scrap flow model of chromium recycling in stainless steel, would be a logical agency to undertake this analysis. Cost of preparing new material flow models would vary, but would probably be less than $100,000 per application addressed. The original appropriation for the two models mentioned above was provided to the Bureau of Mines under the Defense Production Act through the Federal Emergency Management Act. Update of these models would cost about $50,000 per application.

At present, limited national level information is available about "hidden inventories" of strategic materials that could potentially be recycled in the event of a supply disruption. (Stockpile management estimates about recycling levels in a supply disruption are based on economic analysis, not estimation of materials.) Hidden inventories include scrap inventories that for one reason or another are not reported to the Bureau of Mines and potentially reclaimable mining tailings and industrial waste materials. Such inventories can be quite large. At one Gulf area petroleum catalyst recycling operation, for example, perhaps as much as 7 million pounds of cobalt-nickel aluminate slag has accumulated over the years. This material would not be economic to recover without major increases in cobalt prices, and some technical problems in recovery would have to be overcome. In a supply disruption of protracted length, however, it may represent a recoverable resource. In addition, a large quantity of strategic materials are present in mine tailings which maybe potentially reclaimable. Although information is available about strategic material content of some of these tailings (e.g., cobalt tailings from lead zinc mining in Missouri), their national magnitude is not known accurately.

The importance of information can, of course, be overstated. It would not be necessary, or even desirable, to attempt to inventory comprehensively all low-grade sources of strategic materials, for example, to derive plausible estimates of the magnitude of such resources. Nor are current information deficiencies so great as to prevent identification of applications and materials in which there is potential for major increases in current recycling levels. However, an institutional mechanism for periodic reexamination of recycling and conservation trends and opportunities would be highly useful in policy formulation.

The Impacts of Federal Activities on Recycling

The Federal Government influences recycling of strategic materials both directly and indirectly. Direct effects arise from its R&D activities aimed at improving recycling technologies. This research has had a demonstrable effect in encouraging increased recycling of strategic materials; many currently used processes were initially developed with Federal support.

Indirect effects—some positive and some negative—arise from a wide variety of Federal policies and programs that are not specifically aimed at recycling. Such activities as taxation, regulation of transportation rate setting, environmental policy, and procurement and disposal of materials by Federal agencies can affeet material flows in the economy. Several recent laws have attempted to remove inadvertent bias in Federal regulations that may favor virgin raw materials over recycled materials, but the recycling industry continues to be concerned that Federal policies may discourage recycling.[38]

The National Materials and Minerals Policy, Research and Development Act called on the president to:

> . . . assess Federal policies which adversely or positively affect all stages of the materials cycle, from exploration to final product recycling and disposal including but not limited to, financial assistance and tax policies for recycled and virgin sources of materials and make recommendations for equalizing any existing imbalances, or removing any impediments, which may be created by the application of Federal law and regulations to the market for materials . .[39]

The President's materials plan did not specifically address this issue. (The plan placed such analysis in the overall context of its regulatory reform assessment, an approach that is not specific enough to suggest improvements for strategic materials recycling.)

Such an evaluation and recommendation process—especially if focused on strategic materials—could help identify possible changes in Federal programs that could encourage greater or more effective recycling of strategic materials (table 8-9, issue 2). This cannot be done with a narrow focus simply on strategic materials: overall objectives and missions of Federal programs must be taken into account, even if a particular program or policy may adversely affect recycling.

Nonetheless, there may be ways to encourage recycling while meeting these broader objectives. One area meriting further examination concerns possible connections between waste disposal policies and recycling. Spent cobalt-molybdenum hydroprocessing catalysts, for example, may contain trace amounts of lead and arsenic that may make them potentially hazardous. Although spent catalysts are not a listed hazardous waste, generators of spent catalysts often treat them as such, and as potentially subject to Federal regulations which restrict storage of hazardous wastes on site to 90 days. As a result, within 90 days, generators of spent catalysts must decide whether to send the material for recycling or to landfill the material at an approved site. In the late 1970s, recyclers of spent cobalt catalysts would often pay generators $300 per ton to obtain this material in order to recycle molybdenum. In the 1982-83 period, generators often needed to pay the freight to have the spent catalysts sent to the single U.S. firm still recycling those catalysts for molybdenum values. As a result, landfilling is often a more attractive option, and simply storing the material on site while waiting for metal values to increase is precluded. An estimated 270,000 pounds of cobalt were not reclaimed from spent hydroprocessing catalysts in 1982.

The impediments to recycling cobalt catalysts are thus largely economic in nature, arising from the low value of metals at the present time, but Federal hazardous waste regulations may inadvertently cause premature loss of cobalt values. It would be inappropriate to change Federal policy with respect to hazardous waste simply to facilitate recovery of strategic materials in circumstances such as this. However, with appropriate safeguards, it may be possible to develop alternatives to encourage recycling of strategic materials while safeguarding concerns about public health and safety arising from hazardous waste storage. Possible alternatives to encourage recycling of strategic materials from some hazardous waste include intensifying the recycling R&D activities by the Bureau of Mines to assist industry in developing effective reclamation technologies; possible use of guaranteed purchase agreements under the Defense production Act to defray the expense of reclamation when it is currently not economic; longer term but temporary storage of some hazardous wastes contain-

[38] For a discussion of the concerns of the recycling industry about Federal policies, see National Association of Recycling Industries, *Recycled Metals in the 1980s* (New York: National Association of Recycling Industries, 1982), pp 167-177.
[39] Public Law 96-479, sec. 4(8).

ing strategic materials in regional repositories where they would be available for subsequent recycling; and possible use of "waste end" taxation, which could make landfilling less attractive as a disposal option by taxing generators of wastes when they are landfilled.

Increasing interest exists in strategic material recycling opportunities associated with surplus Federal property—especially that of the Department of Defense. GAO is currently auditing Department of Defense scrap generation levels and possible alternative means of disposal of scrap at the request of the House Armed Services Committee. However, the GAO effort is focused principally on aluminum—not on superalloy scrap.

Military aircraft contain large quantities of strategic materials that are potentially recyclable at the end of their service life. Currently, most jet engine parts are declared surplus and are sold as scrap at the end of their useful service life, Generally, obsolete superalloy scrap is downgraded for its nickel and chromium content, so that other metals (e.g., cobalt) are not beneficially used.

Alternatives to disposal of surplus scrap could have strategic material conservation benefits. The Department of Defense and the General Services Administration can promote advancement of recycling technologies and processes by contributing surplus scrap to demonstrate advanced recovery methods.

A model and precedent for a government-run recycling program exists. For nearly a decade, the Department of Defense has conducted a precious metals recovery program (including platinum, palladium, and rhodium) from surplus, damaged, or outdated government property. The recycled materials are refined to a high level of purity and may then be used as government-furnished materials in defense contracts and in certain other government contracts. Savings to the government from this program have been very large because the costs of recovering and refining PGMs are cheaper than purchasing new material.

At current cobalt prices, this would not be the case with regard to superalloy reclamation. An Air Force working group established to assess a feasibility study on a cobalt reclamation process for obsolete jet engine parts reached the conclusion that it would be cheaper for the government to sell these parts as scrap, given current cobalt prices, (The working group did not identify costs associated with the various alternatives.) This argument fails to take into account the strategic benefits of having a domestic capability to reclaim individual elements from scrap in the event of a supply emergency.

Besides evaluation of agency programs to determine whether changes may be needed in Federal policies with respect to recycling, the Federal Government can heighten visibility of recycling industry issues through special studies.

The National Materials and Minerals Policy, Research and Development Act of 1980 established a continuing assessment function in the Commerce Department to undertake case studies of specific material needs to ensure "an adequate and stable supply of materials to meet national security, economic well-being and industrial production needs. " To date, studies have been completed on the steel industry, and the aerospace industry, and a study on the domestic mining industry is in progress, Although such studies may address recycling to some extent, special assessment of key components of the recycling industry would aid in understanding the role recycling could play in providing strategic and critical materials and in the identification of economic 'and institutional barriers to increased recycling.

Developing New Recycling Technologies

Recycling of strategic materials often entails highly sophisticated technologies and processes. The increasing complexity of materials used in end products, such as jet engines and automobiles, and the general trend toward more stringent material specifications, require adjustments in segregating and processing scrap by recyclers. As a result, extensive R&D activities are often needed to keep pace with changes in end products.

Substantial technical advances have been made in recycling technologies in recent years, and many of these advances have been supported by government research. Increasingly, as government funds for general recycling research have become more limited, available funds have been targeted on strategic materials, including processes and technologies to effectively reclaim them from low quality materials (e. g., obsolete scrap) that are not now processed.

Several Federal agencies, including the Department of Defense, NASA, and the Environmental Protection Agency, have sponsored recycling R&D activities relevant to strategic materials. However, the Bureau of Mines is the primary Federal recycling research agency. Recent Bureau projects have emphasized, among other things, development of processes to enhance recovery of cobalt, nickel, and chromium from materials such as superalloys and stainless or specialty steel scrap and wastes. Funding of strategic materials recycling activities has been maintained at a high level through reprogramming of funds from other areas.

Normally, industry itself assumes the key role in actually developing new technologies arising from Bureau research. Many currently used processes pertaining to recycling of steelmaking wastes, cemented carbides, and other materials were originally developed or sponsored by the Bureau of Mines. At least seven companies, for example, are using a Bureau-patented process which permits effective recovery of cemented carbide scrap, with its cobalt values.

Current metal prices do not justify private investment in post-laboratory development of some experimental recycling technologies—especially those for superalloys—that promise to substantially improve recycling of strategic materials, Superalloy raw materials provided through recycling will increasingly depend on effective obsolete scrap recovery since manufacturing processes are reducing the amount of home and prompt scrap available.

Several commercially used processes can be, and to a limited extent have been, used to recycle obsolete superalloy scrap to provide master melts suitable as raw materials for jet engine superalloy. Alternative processes that reclaim individual elements from the scrap in highly purified form have been demonstrated only in the laboratory.

Experimental reclamation processes of this sort have been developed under Bureau of Mines' sponsorship, and independently by some companies. Proof that they would work in commercial-scale operations has not been ascertained, and an additional 2 to 5 years of work may be needed to reach definitive conclusions.

One Bureau-sponsored experiment, undertaken in the late 1970s, demonstrated the technical feasibility of separately reclaiming individual elements from superalloy scrap, including cobalt, chromium, and nickel—an important breakthrough if the technical merits of the process hold up outside of the laboratory. Industry feasibility studies for a pilot plant and small commercial facility showed promising profit potential at 1980 prices (cobalt was then selling at $25 per pound), but when prices fell, so did interest in the project. (The price of cobalt that would allow this process to break even is confidential information with the company that developed the feasibility study.) Other Bureau of Mines' processes, including one which rapidly dissolves metals out of the superalloy scrap, may also have the potential to advance superalloy recycling technologies. Some private firms, as discussed in chapter 6, have undertaken laboratory research in the area of reclamation. One of these firms currently recovers cobalt from various scraps (including superalloy grindings) for use in cemented carbides, and is considering possible applicability of the process for recycling superalloy per se.

Although government's role in commercializing specific new technologies is usually limited, overriding national objectives, such as na-

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tional security, may justify exceptions. Further development of advanced superalloy recycling processes may well be such a case. One alternative would be for government (in consultation with industry to select the most promising candidate processes) to sponsor one or more pilot plant projects to demonstrate advanced reclamation processes—either at a government facility or under contract with industry (table 8-9, issue 3). The costs of a pilot plant project, probably entailing $5 million or more per project facility plus $1 million to $2 million in operating costs, need to be viewed in terms of the potential benefits and increased supply security that could accrue to the United States in the event that such technologies are commercially viable. Commercial availability of such technologies could give U.S. firms the technical capability to recycle most of the cobalt that is now lost or downgraded, estimated at 2.8 million pounds in 1980.